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DESIGNED AS

A TEXT-BOOK

FOR

INSTITUTIONS OF LEARNING.

BY

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WITH QUESTIONS.

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P R E F A C E.

I HAVE aimed so to write this book, that it shall be fitted both for general reading, and for instruction. It is designed for the family as well as for the school. It seemed desirable that these two objects should be accomplished at the same time, and I have not found them to be at all incompatible. The instruction needed by the family on this subject does not differ from that which is required in the school-room, either in regard to the facts to be communicated, or the manner in which it should be done. No one will question the truth of this, so far as the facts are concerned. But it is true even as to the mode of communicating them. In both cases there need to be clearness in statement, and fullness of illustration. Actual instruction is to be given in both cases, and to minds that are very nearly in the same attitude. I could not, therefore, see the necessity of writing a book on this subject for the people which should differ from one written for the school. Besides, it has seemed to me desirable that there should be a greater community of interest between the school and the family than as yet exists; and this object, books equally interesting to both will tend to promote.

I have avoided technical terms so far as possible. Whenever they are used they are sufficiently explained at the time, so that no glossary is needed. Some points commonly considered hard to be understood are treated of, but I have endeavored to simplify them, by full illustration, and by a presentation of the truth uncomplicated with speculations and hypotheses. And these points are so introduced, that the mind is prepared by the previous investigation to understand them. I have aimed so to arrange the topics, as to have a preparation constantly going on in the mind of the student, fitting him for the proper understanding of what is to follow. By this natural gradation in the development of the whole subject some of the deep things in Physiology can be made clear, which it would otherwise be impossible for the student to understand.

Although Physiology is becoming a prominent study in the schools and colleges in some parts of our country, its importance is no where as yet appreciated as it should be. It should be made a regular branch in our Educational System. This has been already done in France. "A competent knowledge," says Carpenter, "of Animal Physiology and Zoology is there required from every candidate for University

honors; and men of the highest scientific reputation do not think it beneath them to write elementary books, for the instruction of the beginner."

The importance of Physiology as a study, will appear from various considerations.

Many of the subjects comprised in Physiology have, in the case of most students, been already studied in a different phase, or mode, in other branches. Thus, if the student has attended to the Mechanical Powers in his Natural Philosophy, he finds in the human body the principles of the pulley and the lever illustrated in great variety and perfection. The principles in relation to strength in the form and arrangement of structure he sees exemplified in the framework of the body in the most admirable manner. If he has studied Hydraulics, he sees in the body the most perfect, and at the same time the most complicated hydraulic machinery, working incessantly throughout life in the circulation of the blood. The principles of Pneumatics he finds applied in the respiration—those of Optics in the eye—those of Acoustics in the ear—and those of Musical Sounds in the apparatus of the voice. And then, his chemical knowledge meets with new applications in his observation of the changes and the processes going on in the body.

The relations, then, of Physiology to some of the common branches taught in the higher classes in schools, are of the most intimate character. Physiology, in part, merely extends these branches into a new and interesting field; and the student who has once entered this field recurs to these same branches with a renewed interest. Hydraulics, Pneumatics, Optics, &c., have now a new attraction for him, from this, to him novel, application of their principles. The interest thus awakened in his mind is worth much in itself, aside from the mere addition made to his knowledge. And the interest is enhanced by the consideration, that in the human body he sees the applications of these principles to mechanism that exhibits the skill of perfect wisdom and almighty power.

But there are relations of Physiology to still other studies which should be noticed.

The analogies that exist between the human body and all other living things, in relation to structure and growth, are numerous and striking. Though life is so diverse in its processes and in the forms which we see it evolve in the whole range of animated nature, it in some important respects displays a great similarity, which it is interesting to trace throughout its diversified manifestations. Growth, or nutrition, as you will see in the following pages, is essentially the same in the Plant as it is in the Animal. Botany, therefore, taught as it should be, has quite an intimate relation to Animal Physiology. The Science of Life is, in many respects, one Science; and if, in studying any of its subdivisions, we fail to take this broad view of it, and to trace

out the analogies referred to, we lose a large part of the interest of the study. Human Physiology, the subject of study in this book, is but a part of a science which offers to the student wide fields of observation exceedingly diversified and full of interest. This being so, I could not avoid in the following pages making occasional references to the analogies existing between the phenomena of life as exhibited in the human system, and those which we see in the living world around us; and as the student proceeds with the study, he will find himself interested in these in whatever form they are presented.

This leads me to say that this study of nature, in its broad common relations and its beautiful and extensive analogies, should be made very prominent in our systems of education. It is the application of the principles of abstract science to the forms, and especially the *living* forms of nature all about us, that gives interest to these principles, and makes us to understand and appreciate them. It is here that we find a very serious defect in the prevalent mode of education, even at the present time, notwithstanding all our improvements. We live in the midst of a material world, animate and inanimate, and have daily converse, so to speak, with material forms of every variety, presenting phenomena of the highest interest and of endless diversity. And yet, through almost all the period of childhood, and perhaps we may say youth also, this book of nature is in the school-room very nearly a sealed book. The very process of education shuts in the pupil from this broad contemplation of the world in which he lives. He is drilled through spelling, reading, grammar, &c., but he is left in total ignorance of the beautiful flowers, and the majestic trees outside of the school-room. How very few even of thoroughly educated adults, know the processes by which a plant or a tree grows! And the same can be said of other phenomena of nature.

The defect which I have pointed out runs through the whole of education. We can see it even in the prevalent mode of teaching the natural sciences themselves. One would suppose that here the facts, the phenomena, would command the chief attention of the teacher and the student. But it is very commonly not so. The mere technicalities and the classification are made much too prominent. Botany, really one of the most interesting of all branches of natural science, is thus ordinarily made one of the driest of studies. *To teach this aright, the phenomena of vegetation, so varied and so beautiful, should constitute the chief material of instruction, and the mere classification should be considered, although necessary, as wholly a secondary thing.*

The great facts of the world, both of mind and matter, should furnish really the *material* for education, and those branches that are ordinarily pursued with such assiduity should be considered as merely subsidiary to the teaching of these facts. The whole order of education must be reversed. Instead of beginning the child's education with

learning to spell and read, the object should be to make him an observer of nature, and the spelling and reading should be done in connection with this, and as subsidiary to it. Things and not words, or mere signs, should from the first, constitute the substantial part of instruction. The child should be made, at home, in the school, and everywhere, a naturalist in the largest sense of that word. We should aim to impart to him a spirit in consonance with the following precept of Hugh Miller, the famous self-taught geologist: "Learn to make a right use of your eyes; the commonest things are worth looking at—even stones and weeds, and the most familiar animals."

As it is now, no one becomes a naturalist early in life, except in spite of the tendencies of his education. The study of nature is not only not encouraged, but is absolutely discouraged in our educational system. If any one, like Hugh Miller, by the force of a taste that can not be repressed by the training of the school-room, undertakes to make a "right use of his eyes," and curiously examines "stones and weeds," he is regarded by the world of spellers and readers and grammarians and cipherers, as a strange genius. But he is pursuing, from an irresistible internal force, the very course that I would have every student, even from his childhood, encouraged to pursue, in a measure at least, by the external circumstances of his education. The tendencies of his training should be decidedly in this direction.

If the general mode of education were changed in the manner indicated, education would have much less of the character of mere drudgery than it now has. Not that there would be any the less labor; but the labor would be made lighter by the interest imparted to it—the interest which always results from the study of facts and phenomena, and never from the learning of mere words and technicalities and classification. I would gladly dwell on this subject, and show by varied illustrations how the mode of instruction referred to, should be pursued, and especially with younger scholars; but the limits of a preface will not allow me to enter so large a field.

The change which I have pointed out can not be effected at once. It will require time. Confirmed traditional customs are to be done away, the habits of teachers are to be altered, and the proper books are to a great extent to be yet written, especially such as are fitted for the first years of education.

If the study of nature should be thus made prominent in education, human physiology would be considered altogether its most interesting and important branch, and for several reasons. First: there is nowhere to be found so curious a collection of mechanisms, or so interesting and wonderful a series of processes, as in the human body. In nothing else in the wide world are the principles of so many departments of science so extensively and perfectly exemplified. Life works here its most complicated set of machinery. Secondly: the singular

and mysterious connection of the immaterial and immortal soul with the material and perishable body, gives intense interest to this study. In Physiology we do not study matter alone, or spirit alone, but both matter and spirit united, and often acting together. This circumstance distinguishes this from all other studies. Thirdly : it is *our own* frames, moved by the spirit within us, that we study. The subject has a personal interest for us that is not presented by most studies, and by none in so large a degree as in this. And, fourthly : the study is of great importance, because a judicious and efficient Hygiene must be based upon a knowledge of the laws of physiology. We can not know how to keep our functions in the condition of health, without understanding the laws that regulate them. I have said but little in this book in regard to hygiene, and that only incidentally, because that subject would require of itself a whole volume to elucidate it properly.

I have not thought it proper to indulge to any great extent in those reflections which the contemplation of so perfect and diversified a congeries of mechanisms as are presented in man would naturally suggest, in regard to the skill of the great Builder of the universe. Such reflections would extend the book to too great length. Besides, they are so readily suggested to the mind of both teacher and scholar, that it is entirely unnecessary for the author to dwell on them.

I have treated of some subjects on which, from the difficulty of understanding them, there has been a disposition in many minds to go beyond what we know, and indulge in unwarranted speculation. On these points I have taken pains to draw the line very distinctly between what is known, and what is supposed. I deem it important to prevent the minds of the young from being led away from the simple truths of science by ingenious speculations and plausible reasonings. Let me not be understood to decry all hypothesis. I object only to the mingling of facts and suppositions together in one indiscriminate mass, as is often done. The disposition to do this, which is more common than is generally supposed, exerts so injurious an influence upon the habits of the mind, and so confuses its views of truth, that we ought to look upon it as one of the most serious evils to be guarded against in education. It is really one of the most prominent obstacles to the progress of truth on all subjects, both in individual minds, and in the minds of the community at large. This disposition, so apt to be fostered in the enthusiastic mind of youth, by ingenious but dreamy speculations, should be corrected at the outset, and the mind should, in its forming stage, be habituated to the discrimination between the proved, the true, and that which rests on presumptive, perhaps merely plausible evidence. This discrimination should therefore be exemplified in books designed for instruction, and this I have attempted in the present volume.

SUGGESTIONS TO TEACHERS.

IN order to be able to teach from this book properly, the teacher should himself study all of it thoroughly before he begins his instruction. If he merely keep a little in advance of his class, he will fail in his conceptions of the general scope and plan of the book. If the interest of the subject awaken in him and in his pupils a spirit of inquiry, there will be a continual looking forward to points which are explained and illustrated further on in the book.

Now if the teacher has made himself master of all the subjects treated of, instead of turning off the inquiry of a scholar without an answer, or even the promise of an answer in the future, or endeavoring to clear up the points about which inquiry is made, which of course he can do, under the circumstances, in an imperfect manner at the best, he can satisfy the scholar by informing him that these points will be found explained in their proper place at a future stage of the investigation.

I have aimed to have every topic treated of in its right place in the development of the general subject, and the teacher should be thoroughly master of the whole book at the outset, in order that he may fully carry out my plan in the mode of developing the topics to the minds of his pupils.

It must be obvious to any teacher that he can teach the minutiae of the subject with more of interest, to say nothing of thoroughness, if, while doing it, he takes in the general views presented, and has in mind the relations of the particular topics in hand to other branches of the subject. Indeed it will be profitable occasionally for the teacher to afford the scholar some glimpses of the interesting fields to be explored further on, taking care, however, not to anticipate so much as to mar the natural method and order of developing the whole subject, which I have taken such especial care to observe in the preparation of the work.

The teacher should read the book through *in course*. If, instead of doing this, he opens to some chapter in the middle or latter part of the book, he may get the impression that too high matters are treated of, and that the minds of his pupils are not competent to understand them. They cannot be understood unless there be a preparation of mind for them; and just this preparation is aimed at in the first part of the book. And besides, it is quite important that the subjects treated of should be developed to the mind of the teacher in the same order in which they are to be developed to the minds of his pupils.

In the engravings, clearness has been aimed at rather than beauty. Yet I should not do the engraver justice if I did not say, that in beauty they are generally quite equal to those which we find in our standard professional works on physiology. It is to be borne in mind that wood-cuts cannot represent correctly the beauty and delicacy of living structures. These can be realized only by seeing the structures themselves. Another thing to be kept in mind is, that parts which are represented in engravings with definite lines for the sake of distinctness, are ordinarily not thus distinct in the structures. To make them so, the dissecting knife must separate them, and take off the cellular substance, which, as the general packing material of the body, everywhere connects adjacent parts together.

The teacher can be aided very much in giving his scholars a correct idea of different organs, by presenting to them organs taken from the bodies of animals. Thus, in giving them an idea of the lungs, the lungs of a calf or a sheep can be used. A pipe may be fastened into the windpipe; and by blowing into this, you can show how the lungs are inflated. An idea of the appearance of the human brain can be given by means of the brain of a calf, or any other animal of sufficient size. An ox's heart may be used in showing the structure and arrangement of the valves and other parts of that organ, for they are essentially the same as in man. A very good idea of the arrangement of the cartilages that make up the larynx, can be obtained from the larynx of an ox or a cow. The general shape and arrangement are the same as in man.

It is some trouble to clear the parts of muscular substance, but the teacher can get some physician or medical student to do it for him. When the preparation is once made, it can be dried for permanent use. I have one which I made twenty-five years ago. In drying, it will be necessary to keep the wings of the thyroid cartilage apart by a wedge, and the supple epiglottis must be placed in such a position as not to interfere with a view of the interior of the larynx. The large eye of the ox can be made use of to show the various parts of that organ, and also to show the formation of the images of objects on the retina.

One great advantage of thus using parts from different animals is, that a taste is given for the examination of the phenomena of life, with its wonderful mechanisms, wherever they may be seen. All living nature thus becomes full of suggestive interest to the young student.

There are some things of which plates can give no correct idea. Such, for example, is the cellular membrane. The attempt to represent it is made in most books on physiology, but it is an entire failure. I have a plate representing its cells as seen in a dried preparation under the microscope; but to give the scholar an idea of it as it appears to the naked eye in its natural condition, I refer him to it as seen in any common piece of meat between the muscles and between

the fibres of each muscle. The teacher can use a piece of meat for this purpose. The difference between muscles, tendons, and ligaments can be shown in the same way.

Those figures which are mere diagrams it will be well for the scholar to draw on the blackboard, and his skill in description and remark may be exercised for his own benefit and for that of the class. He should be trained in this exercise in such a way that he will acquire the power of giving well-proportioned and well-arranged descriptions, without the aid of prompting by minute questions from the teacher.

It will be proper to say something of the use which should be made of the questions that I have prepared. I have two reasons for not placing them at the foot of the page. One reason is, that the book is designed for general reading as well as for instruction. But the chief reason is, that I wish to prevent a too free use of questions on the part of both teacher and scholar. The marking with the pencil of parts which contain the answers to the questions, so often done in our schools, should never be permitted by the teacher, for reasons that I need not stop to notice.

The scholar should read the text at first without reference to the questions; and then the questions can be made use of, perhaps with profit, to fix definitely in the mind the principal points that are brought out. It will be a useful exercise for the scholar, after reading a page or two, to think over the main points, and then see by the aid of the questions whether any important point has escaped his recollection, or failed to make the proper impression on his mind.

The questions that I have constructed will, I think, be found to be fitted to the great majority of scholars. But of course the teacher will vary them to suit the different capacities and mental attitudes which he finds in his class.

It is best not to have an uniform mode of asking questions, even with the same scholar. Variety should be given to the mode of hearing the recitation. Sometimes the questions should be minute, and at other times the mind of the scholar should be left to go on with as little leading as possible.

The scholar should be encouraged occasionally to give the substance of a whole paragraph, or even of more than this. In doing so, any failure in arrangement or proportion can be noticed by the teacher, for the benefit not only of the scholar that is reciting, but also of the whole class. The general scope of an argument may also be given in the same way, and the manner of doing it be made the subject of criticism.

The numbers attached to the questions refer to the pages, this being more convenient to the scholar than a numbering by paragraphs would be, though of course it cannot be quite so definite in all cases.

PHYSIOLOGY AND HYGIENE.

CHAPTER I.

ORGANIZED AND UNORGANIZED SUBSTANCES.

1. The Crystal and the Plant are both wonderful *growths*. The crystal was once a minute nucleus, and the plant was once a little germ.

In one respect they are alike in their growth—both have increased from particles taken from things around them. But the processes by which this is done are different in the two cases. The crystal has increased or grown by layer after layer of particles. Any part of it, when once formed, is not altered. It can receive additions upon the *outside* alone. The plant enlarges by particles which are introduced into passages and interstices. It grows by *absorption* or by *intussusception*.

2. Organs.—This absorption is effected by certain vessels or *organs*, constructed in the root of the plant for this purpose. These absorb or take up fluid matter from the earth. Other organs circulate this fluid through all the plant; and still others use it for the purpose of growth or formation. There are no such organs in the crystal, for it has no *inner* growth. The plant is therefore said to be an *organized* substance or being, and the crystal an *unorganized* substance.

3. Mechanical Principles.—These organs, which thus absorb, and circulate, and construct, do not act simply on *mechanical* principles. They are active agents, and they

perform their duty with a force, and after a manner, for which no mechanical principles can account. No mechanical powers could alone supply the leaves of the mighty tree of the forest with sap from its deep roots; much less could they form those leaves.

4. Chemical Principles.—Neither do these organs act simply on *chemical* principles. While man, through the agency of chemistry, can form some of the crystals which are found in nature, he can not by any arrangement of constituents make a plant, a flower, or a leaf. And the plant, left alone to the action of chemical principles, wilts; and at length ceases to be a plant, and becomes common unorganized matter.

5. Vital Principles.—Mechanical and chemical principles, it is true, are both exhibited to some extent in the growth of plants; but they are under the control of other principles, which we term *vital*. So the plant is not only an *organized substance*, but a *living being*.

6. Animals.—What has been said of plants, in distinction from minerals, may also be said of animals. They are also *organized living* beings, and they have, generally, a more complex organization than plants.

The whole material world, then, that we see around us, we divide into two parts—the unorganized and lifeless, and the organized and living. The distinctions thus pointed out between organized and unorganized matter are essential and fundamental. But let us look at some other distinctions, which either arise from these or accompany them.

7. Other Distinctions between the Organic and Inorganic.—All the parts of the mineral are *independent of each other*, while it is otherwise with the plant or the animal. Accordingly, we do not examine the properties of plants and animals as we examine those of minerals. The chemist can ascertain all the properties of a crystal or a rock if you give him but a small piece of it.

But the botanist can not ascertain all the properties of a plant by looking at some one part of it. If he examine the flower, this gives him no knowledge of the root. In order

to know all about the plant, he must examine every part by itself, and then look at it in its relations to the other parts. The same may be said of the physiologist, in his investigation of the properties of animals.

8. Assimilation in Organized Substances.—As the crystal is forming by layer after layer of particles, no change is effected in these particles as they are becoming arranged in the layers. But in the case of the living organized being, a change is produced in the particles which are taken up by the absorbents. And the change, ordinarily, is both a gradual and a complex one. In the plant, a change is produced in the particles in the very act of absorption; but this change is only the beginning of a process which is afterwards perfected. The sap is not thoroughly fitted for nutrition when it first begins to circulate. It is carried up through the vessels of the trunk or stalk to the leaves. There the last step of the process is taken, and the sap is now ready to be used in the growth of the plant or tree.

So, also, in the animal, the nutritious part of the food, taken up by the absorbents in the digestive organs, is first acted upon by certain little glands, through which it passes, is then poured into the circulation, to be mingled with the blood, and is carried with the blood to the lungs, to be exposed to the air; and thus it is fitted for the nutrition or growth of the body.

This process, which is thus carried on in the plant and in the animal, is very properly called *assimilation*. For the particles that are taken up by the absorbents in the root of the plant are, by this process, made *like* to the plant; and the particles taken up by the absorbents in the stomach*

* The word stomach requires some little explanation, as it is used in physiology in two senses—in a limited sense, and also in an extended one. It is used in its limited sense, as referring to the cavity at the beginning of the *alimentary canal*, as it is termed; this latter term being applied to the series of cavities, the stomach and the small and large intestines, which are found in the digestive apparatus in the higher orders of animals. In comparisons, however, between these animals and those which have a more simple digestive apparatus, the word stomach is used in a more extended sense, as being synonymous

are made *like* the animal. So obvious is this, in the case of the animal, that some French physiologist speaks of the blood as *chair coulante*, or running flesh.

9. Permanency.—Another prominent distinction between organized and unorganized substances is in relation to *permanency*. Constant change appears in all organized bodies; while permanency is written upon all substances which are unorganized. In organized beings, continual change is going on at every point. It is a condition of their being.

This is true, not only of the decline of a plant or animal, but even of its growth. For, in its growth, as the parts enlarge internally as well as externally, they change not only the arrangement of the particles, but, to a great extent, they change the particles themselves. It is true, as well of the towering tree as of the tiny plant, that these changes have been going on during all its growth; so that, at its maturity, it is, both in relation to the arrangement of its particles and in relation to the particles themselves, a very different thing from what it was when it pushed its germ up through the ground, or even when it was but a small tree. So, in all animals, the same internal changes are going on, and to a much greater extent; because, from the activity of their nature, there is wear and tear, and, therefore, refuse matter to be disposed of. As you will see in another part of this book, the human body undergoes these changes very largely.

The crystal, as fast as it is formed, becomes permanent. No changes occur *within* it. In itself, it is unchangeable. It can not change its own particles, as the plant or the animal does. It can be changed only by external addition, or by external diminution, through the influence of agents acting upon its surface.

10. Reproduction.—With the constant changes going on in organic nature, there is constant succession.

with the term alimentary canal. It is used in this sense, also, when, as in the present case, it is referred to in a comparison between animals and vegetables.

Plants and animals produce other plants and animals, and themselves die, making room for their successors. But the crystal does not form other crystals, and then crumble into dust. In itself, it is both *unchangeable* and *unproductive*.

11. Observations of Change and Permanency.—This distinction between organized and unorganized substances, in relation to change and succession, meets the eye everywhere. The mountains, the rocks, and even the stones under our feet, remain the same year after year, while all vegetable and animal life is ever changing its forms and manifestations. There are the changes of growth, and the changes of decay and death, all around and within us; and they are strangely mingled together.

There is death even in the changes of life, as the waste particles are taken away, and are replaced by the new; and life springs out of the very bosom of death, as from decayed nature new forms of vigor and beauty arise. The mountains stand as they have stood, as the passing generations have looked upon them, while the continual changes of vegetation have been going on upon and around them. The seasons crown their battlements with the emblems of their ever-returning mutations of life, decay, and death, and even the mighty trees, that have shed their leaves from year to year, in obedience to the great law of change, but have themselves stood, at length bow their heads to the same law, and give place to other lords of the forest.

From the “everlasting hills,” which thus remain the same, though change is ever about and upon them, man gets the unchangeable and imperishable rock to construct his habitation, while he himself is changeable and perishable—the creature of a day, whose life is as a vapor. He wears the precious stones, and traffics in the golden ores, which have existed from the creation of the world, through all the changing and dying generations, and passes away, leaving them to others as changeable and perishable as himself.

12. Forms.—Another distinction between organized and unorganized substances relates to the forms which they assume. There is regularity in both, but it is different in

each. Unorganized matter is disposed to arrange its particles in straight lines, and with angles mathematically exact.

The tendency is to regularity ; and irregularity is the result of interfering circumstances. A similar disposition to regularity is manifest in organized substances, but in a different manner. They are disposed to curved, rather than straight lines, and seldom make lines or angles with mathematical exactness. We see this law of regularity exemplified both in animal and vegetable life. The leaf, for example, has the same general shape, that is, the same general arrangement of particles, when it attains its full size, that it had when it was small ; and the same can be said of the arm of the man, compared with his arm when a child.

13. Regularity.—This regularity is more wonderful in organized substances than in the unorganized, because it rules in them in the midst of constant change. In the case of the crystal, as there are no internal changes in it, and as each layer of it, when formed, is permanent, regularity is comparatively, so to speak, easily secured. But in the case of the leaf, as it is growing to its full size, and of the arm, as it grows from infancy to be the stalwart arm of manhood, continual change is going on at every point ; and regularity here is obviously a more difficult achievement.

This regularity appears still more wonderful, when we look at the infinite variety of forms in organized matter, in both the vegetable and the animal world. In all these forms, each part of every animal and of every plant maintains its own peculiar plan and contour. Take, for example, the leaf in its endless varieties. How definitely does each variety preserve its individual character, and how easily is it distinguished from every other variety ! The same can be said of every part of every organized being.

14. Persistency of Form.—Another circumstance still must be mentioned, as adding to the wonderfulness of this regularity. It has been scrupulously maintained, through all the changes of the world from its creation, when God pronounced the works of his hands to be “very good.” The leaf of every tree, for example, is like the leaf

of its ancestral trees back to that time ; and so it will be in all its successors to the end of the world. "The trees of the garden," which delighted the eyes of our first parents, and refreshed them with their shade in their innocence, and amid which after their sin they hid themselves from the presence of their Maker, undoubtedly had the same characteristic shapes, and the same leaves and flowers which their successors present to our eyes.

15. Variety of Form.—Again, it is interesting to notice that, in the midst of this regularity, so strictly maintained in each specific form from age to age, there is a measure of irregularity allowed. While each kind of tree, for example, has specific characteristics in the arrangements of branches and other parts, and in the shapes of its leaves, no two trees of the same kind are exactly alike, and there is always much variety in the leaves of the same kind. While the face of man is so entirely different from the face of every other animal, at the same time, among the hundreds of millions of the human family, how uncommon it is to find two faces that are very nearly alike.

16. Symmetry of Halves.—In the animal world, we see remarkable examples of the preservation of regularity of form in the exact correspondence which exists so commonly between the two halves of the body.

The brain has two halves, which are precisely alike, and the same is true of the nerves which are distributed from it. And so of other parts. But, mingled with this symmetrical arrangement of parts, there are other parts which are irregular in their shape. This is the case with the stomach, the heart, the liver, &c. There are some animals which are altogether destitute of this arrangement of two similar halves of the body. The oyster is a familiar example. The shell of this animal is strikingly in contrast, in this respect, with the shells of some other of the bivalve tribe, as, for instance, the common clam.

17. Size.—There is a distinction between organized and unorganized substances, in regard to size. The size of unorganized bodies has no fixed limit. A crystal or a rock

may grow to any imaginable size, if the particles forming it are sufficiently abundant. But organized bodies have limits fixed to their growth. There is, it is true, more or less latitude to these limits; but they are so well defined in the case of most vegetables and animals, that when growth reaches much beyond or below the limit, it is recognized as a remarkable fact.

18. Structure and Elements.—The last distinction, between organized and unorganized substances, which will be mentioned, relates to their *structure*. While unorganized substances are made of one form of matter, either solid or liquid, or gaseous, organized bodies are made of a mixture of fluids and solids. They are therefore more or less soft and flexible; while the solid, unorganized substances are hard and brittle.

There is a still further difference in structure. Organized substances are much more compound than the unorganized. Most of the unorganized substances are composed of only two or three elements. Thus, air is composed of oxygen and nitrogen, water of oxygen and hydrogen; and most of the mineral salts are composed of three elements—as, for example, carbonate of lime, or chalk, which is composed of oxygen, carbon, and calcium, the mineral base of lime.

But organized substances are composed of at least three or four elements and sometimes more. The four principal elements in the composition of organized bodies are, oxygen, nitrogen, hydrogen, and carbon. But there are other elements introduced for special purposes. Thus, carbonate of lime (a combination of calcium with two of the common elements, carbon and oxygen,) is diffused very generally throughout the textures of plants, giving them firmness and strength. In animals of the higher orders, phosphate and carbonate of lime compose in part the framework of the body.

We find iron, too, in the blood. Of the sixty-four elementary substances discovered in mineral bodies, only eighteen or nineteen have been found in plants and animals, and some of these in very small amounts. The *essential*

components of living substances are the four *non-metallic* elements mentioned above—oxygen, hydrogen, nitrogen, and carbon ; while the bulk of the inorganic world is composed of the metals and their compounds, viz., the alkalies and the earths. And it is interesting to observe that, of the four elements which compose the bulk of the animal and vegetable world, both the fluids and the solids, three are gaseous, while but one, carbon, is a solid substance.

CHAPTER II.

THE DISTINCTIONS BETWEEN ANIMALS AND PLANTS.

HAVING pointed out the distinctions between organized and unorganized substances, we will now consider the distinctions between the two classes of organized beings—animals and vegetables ; first noticing those differences which are obvious; and second, pointing out those which are essential.

19. Locomotion.—One of the most obvious distinctions is in relation to *locomotion*. The plant remains in one place ; while the animal moves about, in the air, or in the water, or upon the surface of the earth. And the structures of the animal and the plant of course differ, so as to accommodate these two very different modes of existence.

As the animal moves from place to place, it must, for this reason, if for no other, have an apparatus of nourishment and growth different from that of the plant. The plant, by means of its absorbents in the roots, takes up from the earth, in the form of sap, its nutrition, or food, as it may very properly be called. The moving about of the animal would in itself forbid its deriving its food directly from the earth, even if the earth contained the proper materials for its nourishment.

So a cavity is provided in its body, called a stomach, into which nutritious substances can be introduced. And this cavity is lined with absorbents, which there do for the animal what the absorbents in the roots of the plant do for the plant.

20. Central Organs.—Besides the stomach, there are other great central organs which are peculiar to most animals, in distinction from vegetables—as the heart, the liver, the lungs, etc. Branches and roots may be cut off extensively, and even a large portion of the stem or trunk may be destroyed; and yet what remains of the plant may still live. Even a small portion of it may be made to take root and live by itself. It is not so with most animals. Mutilation can not be carried far without injuring some large organ which is essential to the life of the whole; and no part taken from its extremities can be made in any way to live by itself.

21. Sensation and Voluntary Motion.—Another obvious distinction is this: The higher order of animals are *sentient* and *spontaneously-moving* beings, while vegetables are not. The animal *feels* the action of agents upon it, and this it can not do without consciousness and thought. The evidences of the existence of consciousness and thought, and the consequent spontaneous motion, are very slight in some animals. We see these evidences plainly in the great majority of animals; and we infer the existence of sensation and thought in those exceptional cases, where the evidences are doubtful or absent, as we find in them other marks of animal, in distinction from vegetable life.

22. Exceptions.—The distinction in regard to locomotion, if we look at the animal as a whole, has its exceptions. There are some animals, as the coral animal and the sponge, that are entirely confined to one spot during all their existence. But, while some animals are thus confined, they have the power of spontaneous motion in some of their parts, which is exercised for the purpose of obtaining food, and, in some cases, for the avoidance of danger.

This power is not possessed by any plant. Some few

plants, as the sensitive plant and the Venus's fly-trap, (*Dionaea muscipula*,) exhibit a property which resembles it, but it is essentially a different thing. In these cases, the influence of the stimulus that excites the motion is communicated from particle to particle, from the point where the stimulus is applied; and the motion is only in one direction, and not in various directions, as is the case with spontaneous animal motions.

23. Illustration.—This can be very readily seen, if we compare the motion of the sensitive plant or the fly-trap with those of the little fresh-water polyp called the *Hydra*. This animal, of which an enlarged representation is here given, and also a representation of its natural size, is found in ponds. It attaches itself to any floating object—a stick or straw, as seen in the Figure—by a kind of sucker. Thus supporting itself, it stretches out its long arms, to take for its food any minute worm or insect which may float within their reach. When it catches one, it directs it to the mouth, *a*, which opens into the stomach or general cavity. Now, in doing all this, there is a variety, a compound character in the motion, which is in plain contrast with the simple motion of the leaves of the fly-trap and those of the sensitive plant.

24. Nervous System.—Accordingly, we find a peculiar structure in animals devoted to these functions, and others connected with them. This structure is the *nervous system*. No trace of such a structure has ever been discovered in any plant. If there were any true analogy between animal motion and the motions of the sensitive plant and the fly-trap, we should be able to find in

FIG. 1.



HYDRA.

them traces of nervous structure; for the structure of these plants is so plainly developed, that its constituent parts are easily distinguished. It is true, also, that in some of the lower animals no trace of a nervous system is found.

25. Not Essential to Nutrition.—The nervous system is evidently not essential to nutrition, for this is as well effected in the plant as in the animal. This is accomplished in both in substantially the same way. The means by which it is done, and its arrangements, are modified, in the two cases, to suit the differing circumstances.

26. Functions of Organic Life and of Animal Life.—The nervous system is, for particular purposes, superadded in the animal to what is common both to the animal and the plant, and so constitutes the essential difference between them. And so, all the functions relating to nutrition, which are common to plants and animals, are called functions of *organic* life. But the functions which are performed by the system superadded in the animal, the chief of which are sensation and spontaneous motion, are termed functions of *animal* life. These are sometimes also called functions of *relation*, from the especial connection which they form between the animal and all that is around him.

27. Thought and Will.—These animal functions, sensation and spontaneous motion, imply thought and will. The order of action is this: sensation—thought in regard to it—action of the will in consequence of thought—then, from this action, an impression carried through nerves to organs termed muscles—motion in them from their contraction.

This order, however, is not always observed. The first link, sensation, may be absent. Thought, without any preceding sensation, may prompt the will, and spontaneous motion results. The action of the will, too, may be left out, or may be in opposition. Thus, emotions may produce action of the muscles, the will not concurring, and perhaps opposing; as when we laugh at what is ridiculous, or weep at what is sad, in spite of restraining efforts dictated by the will.

28. *Chemical Constituents.*—One more important distinction between animals and plants remains to be noticed. Organized substances are composed mostly of four elements—oxygen, hydrogen, nitrogen and carbon. Plants differ from animals, in having but little nitrogen in their composition. It was formerly supposed that they contained none of this element. It is found only in particular parts of plants, as the seeds. We may regard carbon as the most characteristic constituent of vegetables, and nitrogen of animals. And in this connection it is interesting to observe that, while carbon is largely thrown off from the lungs of animals, in the shape of carbonic-acid gas, it is as largely absorbed by the leaves of plants. Of this fact more particular notice will be taken when the subject of respiration is reached.

CHAPTER III.

MAN IN HIS RELATIONS TO THE THREE KINGDOMS OF NATURE.

29. *Peculiar Endowments of Man.*—Man is commonly spoken of as being at the head of the animal kingdom, and in the book of the naturalist is made an order of the class termed Mammalia. As the basis of the whole classification is mere material organization, and has no reference at all to mental or spiritual endowments, the classification, in regard to man, is in its principle correct.

At the same time, it must be admitted, that it fails to recognize altogether the *essential* distinctions between man and other animals. These distinctions, making, as they do, a wide gap—"an impassable chasm," as Professor Guyot expresses it—between man and the inferior animals, are to be found in certain peculiar spiritual endowments which man possesses.

30. Abstract Reasoning.—One of these endowments is the power of *abstract reasoning*. Other animals, in a certain sense, reason, that is, they make inferences; but they never arrive at any general or abstract truths.

31. Conscience.—Another endowment is a moral one, linking man in his spiritual nature to the Deity: this is *conscience*, or the knowledge and sense of what is right, in distinction from what is wrong. Other animals, in obedience to the passions of fear and love, sometimes appear to the superficial observer to have an idea of what is right, as such; but there is not the slightest evidence that they really have any such knowledge.

32. Immortality.—The force of this view of the subject is enhanced, if we take into consideration the great fact, revealed to us by God in his Word, that man is destined to *immortality*. It may be objected that, as this fact is learned only by revelation, and not by observation, it is not to be regarded as a scientific fact.

But, granting that there is truth in the objection, it certainly is allowable to allude to the revelations of Scripture, as confirming or enforcing views developed by scientific observation. The view here presented is based upon endowments that are recognized by the scientific observer, without the aid of revelation; and we can appeal to the revealed fact of man's immortality, as adding force to this view, and not as being at all necessary to the establishment of its truth.

33. Real Relation to the Animal Kingdom.—The grand essential distinction between animals and plants lies, as you have seen in the last chapter, in the fact that animals have a nervous system. Now, with this system, as you have also seen, appear certain mental manifestations. These differ widely in different animals, and are most prominent in those in which this system is most prominent and complicated. As we trace upward these complications, when we come to man, we find certain mental manifestations, which separate him by "an impassable chasm" from all other animals.

Till we arrive at him, the difference is, for the most part, one of *degree*. But in his case it is a difference of *kind*, and a very wide one. Of such a difference the naturalist should certainly take very distinct cognizance ; and, if it be not consistent for him to do so in his classification, great force and prominence should be given to these views in his instructions on this subject. As the superadding of the nervous system separates the animal from the plant, so, also, as Professor Guyot very justly maintains, the superadding of such endowments as we find in man separates him, by a chasm quite as "impassable," from other animals.

34. The Hand of Man.—The distinction commonly received as the ground of classification for man, is a trivial, perhaps a questionable one. He is said to have two hands, and so makes the order Bimana ; while apes and monkeys are said to have four hands, and are, therefore, considered as making the order Quadrumana.

Now, if we observe carefully and fully the wonderful endowments of the human hand, we shall hardly be willing to allow that the monkey has four such members. With a full view of the capabilities of the human hand, that of the monkey can not be considered as a hand, but as a member possessing some of the properties of both hand and foot.

Hands are given to these animals to enable them to climb with facility, and to grasp their food ; but they have none of that great variety of motion, which is so striking a peculiarity of the hand of intelligent man. The ground upon which they are said to have four hands is that which is thus stated by Cuvier. "That which constitutes the *hand*, properly so called, is the faculty of opposing the thumb to the other fingers, so as to seize upon the most minute objects." No animal besides man has this arrangement, except the Quadrumana. It is claimed, therefore, that they have hands, although they are very imperfect when compared with the hand of man. The imperfection is indeed so great, as to make us at least reluctant to admit the claim set up by the naturalist.

35. Views of Dr. Carpenter.—“While,” says Carpenter, “the thumb in the human hand can be brought into exact opposition to the extremities of all the fingers, whether singly or in combination, in those Quadrumanæ which most nearly approach man, the thumb is so short, and the fingers so much elongated, that their tips can scarcely be brought into opposition, and the thumb and fingers are so weak, that they can never be opposed to each other with any degree of force. Hence, although admirably adapted for clinging round bodies of a certain size, such as the small branches of trees, &c., the extremities of the Quadrumanæ can never seize any minute object with such precision, nor support large ones with such firmness, as are essential to the dextrous performance of operations for which the hand is admirably adapted.”

36. Chin, Erect Posture, Man's Weeping and Laughing.—Man's structure differs in *many* respects from that of the inferior animals. It would make this chapter too long to point out all the differences. As an example of the latter, no animal but man has a *chin*. Every other animal has its lower jaw retreating from the teeth, instead of projecting forward below, as in man.

One of the most important and striking peculiarities of man's structure is that general arrangement which enables him to be in the *erect posture*. No other animal naturally assumes this posture, or is able to maintain it for any length of time; and most animals assume one which is entirely the opposite of this. Even the monkey, when taught by man to stand and walk, is by no means erect, but his lower limbs are crooked, and the moment that he escapes the necessity of being an imitator, he is on all fours.

There is a distinction of an interesting character, which concerns both the nervous and muscular systems. It is this, that no animal but man can shed tears, or perform those muscular motions which are necessary to the acts of weeping and laughing. In view of this marked distinction, man has sometimes been designated as “a laughing and crying animal.”

37. *The Essential Distinctions.*—But the great essential distinctions, to which all the rest are really tributary, are, as has been stated, of a mental or spiritual character. And these should always be made peculiarly prominent, whenever the distinctions between man and the inferior animals are treated of by the naturalist. This should be done, not only because they are essential, but also because all other distinctions are subordinate and tributary to them. It is the mental peculiarities of man, for the most part at least, that render necessary those peculiarities which distinguish his organization from that of other animals.

CHAPTER IV.

BONES.

38. *Structure of Bones.*—From the osseous or bony tissue, the solid part of the framework of the body is made. Bone is composed in part of animal matter, and in part of mineral. The mineral part is mostly phosphate of lime. These two parts of bone are in different proportions to each other in the different periods of life.

39. *Mineral Matter.*—The mineral part in the child is about one half of the bone; in the adult, four-fifths; and in the old, seven-eighths. Bones are, therefore, very brittle in old age, while they are somewhat yielding in childhood. The mineral and the animal portions of bone can be separated from each other. If a bone be put into diluted muriatic acid, the mineral part will, after a time become united with the acid, and the animal part will be left, having the perfect shape of the bone. Thus separated from the mineral part, it is so flexible, that it can be tied into a knot. On the other hand, by subjecting a bone for some time to the action of heat, the animal part can be removed, and the mineral part be left by itself.

40. Animal Matter.—The animal part of bone is cartilage, or gristle. This part is formed first, constituting a sort of mold, in which the bone is to be formed. The mineral matter is gradually deposited in the cells of the cartilage. In the very young child, you can see that this process is not completed, especially if you observe the bones of the head. The bones are not united together, as they are in the adult, and there is so little of mineral matter near their edges, that they can be bent with a very slight pressure. The proportion of mineral matter which is deposited in the cartilaginous bones varies much in different animals. In many fishes, there is almost none of this deposit, the skeleton retaining its cartilaginous character throughout life.

41. Cartilages.—Besides the cartilaginous portion of bones, there are cartilages which are destined to remain so, instead of having mineral deposits made in their cells. The ends of the bones are tipped with them. They are placed between the bones of the spinal column. They also form the connecting links between the breast-bone and the ribs. Cartilage constitutes the body of the outer ear, of the eyelids, and of the lower part of the nose. The transparent part of the eye is formed of cartilage. This substance is placed wherever firmness and tenacity are required without hardness.

42. Function of Bones.—The bones furnish the points of support and attachment for the muscles which move the different parts of the body. They are, therefore, the *passive* instruments of locomotion. They are united together by ligaments of various degrees of strength, according to the necessity of the case.

The bones, forming the framework of the body, not only furnish points of support and attachment to the muscles, but in many cases serve to defend important organs from injury. Thus, the soft brain is thoroughly secured from harm by being inclosed in the skull; and the lungs are surrounded by walls of bone so arranged that, while they defend the lungs from external violence, they secure a

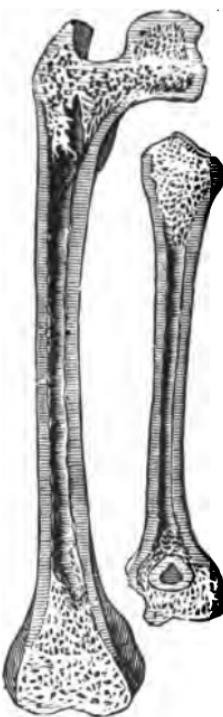
wide range of motion for the necessary expansion of these organs.

43. Structure of Bones.—There are some points of interest in relation to the *structure* of bone and its growth. It has been stated that bone is generally formed in cartilage, the cartilage being formed first as a mold for the bone. Bone is deposited in two forms, solid and cellular. In the flat bones, as in the skull, the cellular structure lies between two plates of solid bone. In the long bones the cellular part is at the two ends, and is covered with a thin plate of solid bone, while the shaft is a hollow tube with the bone very much condensed. This arrangement is seen in Fig. 2, representing the thigh-bone and the bone of the arm.

44. Hollow Cylinders.—Certain well known mechanical principles are observed in this arrangement. The bone would be unnecessarily heavy if it were solid throughout. Lightness in a moving limb is of considerable importance. At the same time strength is to be carefully provided for in a bone which is to sustain the weight of the body, and to which the large muscles of the thigh are attached. By having the bone hollow, both of these objects, lightness and firmness, are secured.

The principles involved are recognized by the architect in the construction of pillars, and we see them exemplified in the hollow stalks of plants. The hollow pillar has more strength than the same quantity of matter would have if in one compact mass; and the stalk which supports the full clusters of grain, would break under its load as it

FIG. 2.



moves back and forth in the wind, if it were solid instead of being hollow.

But the round cavity of the shaft of the bone does not extend to the ends. These are necessarily large, in order to present broad surfaces for articulation with the neighboring bones; and strength and lightness are secured in this case by a cellular arrangement of the body matter, the outer plate of solid bone being comparatively thin. There is obviously more firmness in the resistance to shocks or pressure, secured in this way, than there would be if the bony matter were all consolidated into a shell containing a cavity.

The round canal in the shaft and the cellular structure at the ends are filled with an oily substance called *marrow*. This, like all other fatty substances, is contained in fat-cells. The marrow is also present in the cellular structure between the plates of the flat bones. The cavities and the cells in bones have blood-vessels, branches of arteries and veins that enter the body of the bone at some particular points, in the long ones, near the middle of the shaft.

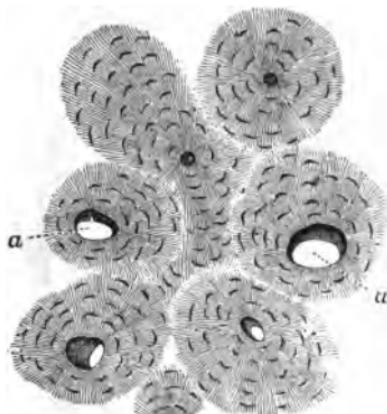
45. Covering of the Bones.—It is from these blood-vessels, together with those that come from the membrane investing the bone, called *periosteum*, that the bone is nourished. But, although an artery runs through the body of the bone, to branch out upon the walls of its cavity, none of its branches enter the very substance of the bone.

46. Growth of Bone.—The manner in which material is carried to every point of the solid bone has been developed by the aid of the microscope. If we cut across the solid portion of bone, and examine it with a microscope, we see here and there orifices of certain minute canals that run lengthwise of the bone.

These canals are found to communicate with the cavity of the bone and receive therefore blood, or some of the constituents of the blood, from the blood-vessels which are situated there. These orifices, as seen under the microscope, are represented in Fig. 3. Around these orifices *a a*, you see little dark spots arranged in rings, with lines running to them from the orifices. By magnifying the section of

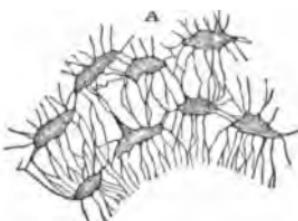
bone still more, we see what these spots and lines are. The dark spots are small cavities, and the lines are minute tubes running to them. In Fig. 4 is a representation of this arrangement as seen in a little portion of the section of bone, more highly magnified than it is in Fig. 3. The tubes pass

FIG. 3.



SECTION OF BONE.

FIG. 4.



out from the canals to the rows of cavities which are around the canals, and thus a circulation is kept up at every point of the solid bone. It is supposed that the blood itself does not circulate in these little channels and cavities in the solid bone, but a fluid containing the constituents of bone. For these channels are too small even to admit the cells which the microscope shows us swimming in the blood. The fluid that circulates in them is selected from the blood, which is contained in the blood-vessels in the cavity of the bone, and in the periosteum that envelopes it.

47. Bones not Sensitive.—It is a very common popular notion, that the bones are endowed with great sensibility, and especially the central part, the marrow. But they have in their healthy state no perceptible sensibility, and the sawing of the bone in amputation occasions no suffering. When, however, a bone becomes inflamed, severe pain is one of the symptoms. If it were not so, disease

FIG. 5.

The Skeleton consists of 201 bones. In this enumeration the teeth, the hyoid bone, and the bones of the ear are not included. Certain bones in the sutures of the head, and in some of the joints, which, though generally present, are not regarded as essential parts of the framework, are also omitted.

NAMES AND CLASSIFICATION OF THE BONES.

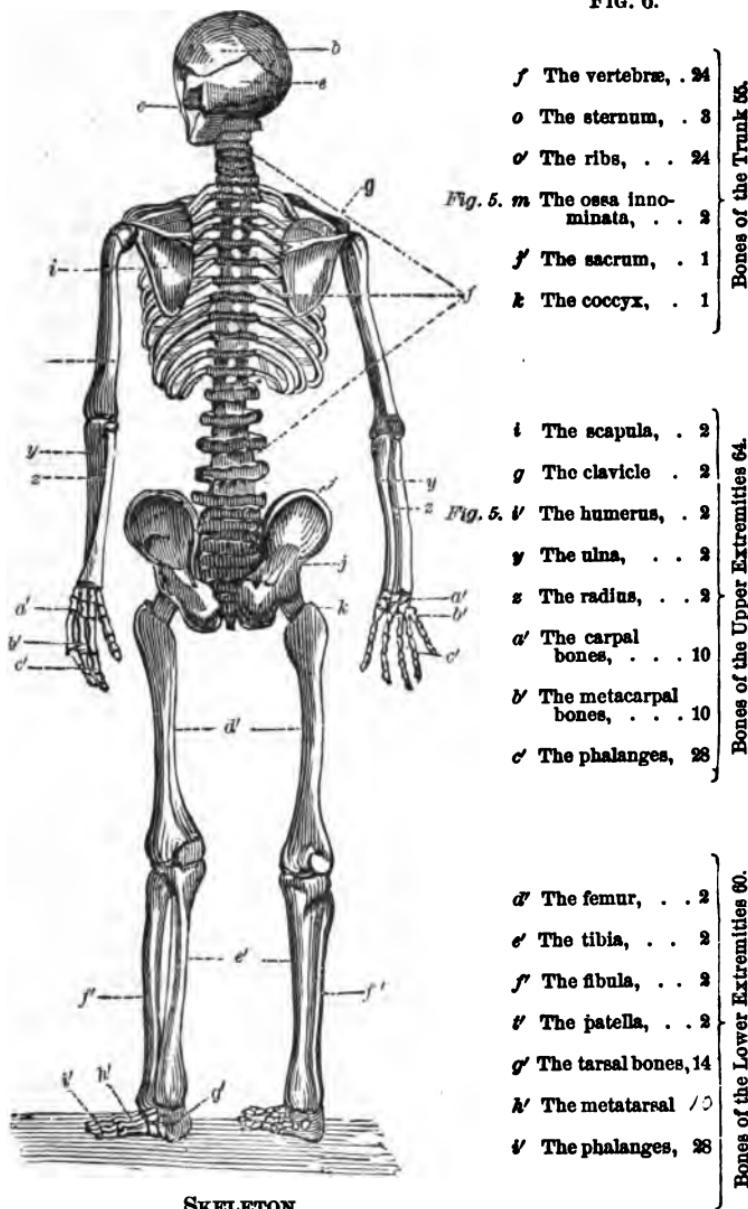
<i>a</i>	The frontal bone, . . . 1	Bones of the Cranium 13
<i>b</i>	The parietal bones, . . . 2	
<i>c</i>	Occipital bone, (Fig. 6) 1	
<i>d</i>	The temporal bones, . . 2	
<i>e</i>	The sphenoid bone, . . 1	
<i>f</i>	The ethmoid bone, . . . 1	Bones of the Face 14
<i>g</i>	The nasal bones, . . . 2	
<i>h</i>	The lachrymal bones, . . 2	
<i>i</i>	The upper maxillary bones, 2	
<i>j</i>	The malar bones, . . . 2	
<i>k</i>	The palatine bones, . . 2	
<i>l</i>	The lower spongy bones, 2	
<i>m</i>	The vomer, 1	
<i>n</i>	The lower maxillary bone, 1	

The bones whose names are marked *†* cannot be shown in the figs.



SKELETON

FIG. 6.



SKELETON.

might go on to produce disastrous results in a part so covered up by others, without any warning of the danger of the case.

48. Shape and Place of Bones.—The bones are of every variety of shape, to suit the various offices which they are to fulfill. You will see this to be true, as you cast your eye over the skeleton as represented in Fig. 5. You first observe the somewhat round box of bones, which contains the brain, and at the same time furnishes sockets for the eyes, extended irregular surfaces for the apparatus of smelling, and for that of the taste, a place for the organs of hearing, and at its lower part, in connection with the lower jaw, a mill for grinding the food. Then you observe the many bones of the thorax or chest, containing and protecting the heart and the lungs.

49. Spinal Column.—The *spinal column*, *f*, composed of twenty-four bones, you see as a firm but movable pillar, extending the whole length of the body, and having its base firmly planted upon that stout thick bone, the *sacrum*, which is wedged in so tightly like the key-stone of an arch, between the broad spreading bones on either side. To this pillar are strongly fastened the walls of the chest; and from the chest thus supported by the spine hang the lax front and lateral walls of the abdomen.

50. Pelvis.—Then below you see the *pelvis*, as it is called,—a set of large bones so arranged in a bowl-form, as to offer a broad surface of support to the contents of the abdomen. The bone called the *ilium*, *m* and *l*, on either side, with its flaring upper surface, is especially serviceable in this way. The pelvis also furnishes a socket for the round head of the thigh bone *s*, and points of attachment for the large muscles that move the lower extremity.

51. Bones of the Lower Extremity.—Observe the large bones of the thigh and leg, intended to give firmness to the lower extremity, and the lighter bones of the arm and forearm, fitted for extent and quickness of motion. Finally notice the numerous bones which enter into the structure of the hand and the foot. These bones, together

with the intervening cartilages, give them great elasticity and variety of motion.

We notice with some particularity some of the bones, of which has been given a general description, as they are united together to form the whole skeleton. We can not notice them all, nor dwell upon every point of interest, for this would require much more space than can be devoted to the subject. We therefore select those points which can be made most clear and interesting.

52. Skull.—Your attention is first called to the bones of the head, as you see them in Fig. 6. There are twenty-two bones in the whole head. Fourteen of these belong to the face, while eight belong to the cranium; that is, that part of the skull which incloses the brain. Of these, notice particularly the large bone in front called the frontal bone, *a*, making the forehead, and below forming the upper portion of the orbits of the eyes; the parietal bone, *b*, the

FIG. 6.



BONES OF THE HEAD.

upper lateral part of the dome of the skull; and *c* the temporal bone on which the parietal bone rests. There is a large bone in the rear forming the back of the cranium as the frontal bone does the front. There are also two bones in

the base of the cranium which are out of sight in this view of the skull. You may, perhaps, be disposed to inquire why this box for holding the brain, should be made of so many bones.

One reason is, that the enlargement of the skull from infancy to adult age is effected more easily and better than it would be if the cranium were one bone. Another reason is, that even in the adult, in whom these bones are at length so tightly united, violence is less apt to produce injury, from the giving, as it is expressed, of the bones upon each other, than it would be if one bone made the whole structure. And this is especially true of the child, in whom the bones are very imperfectly united. Hence it is that the frequent falls of children upon their heads so seldom do any injury.

53. Structure and Union of the Skull Bones.

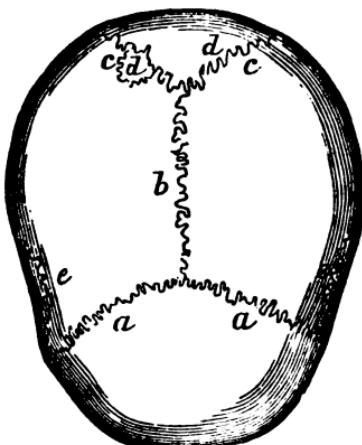
—The principal bones of the head are composed of two solid plates, while the bony matter between these plates is arranged in a cellular or sponge-like form. The outer *table* or *plate* (for both of these terms are used in relation to it) is rather rough, and in some parts has ridges for the attachment of muscles. But the inner plate is very smooth on account of the soft delicate organ that is contained in the cranium. It is so brittle that it has been called the *vitreous* table, from its resemblance to glass in this respect.

The modes of the joining of the bones differ in the two tables. In the outer table the joining is by a minute *dovetailing*, called a suture. Numerous little projections from one bone fit accurately into corresponding spaces in the edge of the other. This is very well represented in Fig. 7, in which you see the sutures on the top of the skull; *b* being the suture which is formed between the two parietal bones; *a, a*, that between the parietal and the frontal bone in front; and *c c*, that between the parietal and the bone which forms the back of the cranium.. A better joining for bones of such a shape as these have, can not be conceived of. But the inner table is joined differently. It is so brittle that the small projections of the dovetailing mode of joining

would not answer here, for they would break very easily. The joining accordingly is in this case by smooth accurately fitted edges, somewhat beveled, so that one slightly overlaps the other.

The upper part of the cranium is in the shape of a dome, and is constructed upon the same principles as such struc-

FIG. 7.



STRUCTURES IN THE SKULL.

tures are as regards resistance to pressure or violence. As in domes that are built by man, so in this dome of the cranium, great strength is secured around the lower part, so as to resist outward lateral pressure. In the dome of St. Paul's there is a double iron chain around its base for this purpose, of course concealed from view. In the head of man the dome may be considered as composed of the frontal bone in front, the parietal bones at the side, and the occipital bone in the rear. In front, the base of the dome is strongly fortified, in the heavy arches that form the upper part of the sockets of the eyes, and on the jutting edges of which are the eyebrows. In the rear the base of the occipital bone is very thick, and is fortified with ridges which furnish attachment to the large muscles in the back of the neck.

But the most marked and interesting contrivance for the strengthening of the base of this dome is at the side. It is where the parietal bone *b*, as seen in Fig. 6, is joined by the temporal, *c*. The joining here is not by suture, for that would afford no resistance to lateral pressure, either outward or inward. To secure this object, the lower bone, the temporal, laps over the upper, the parietal, with a beveled edge. It abuts upon or against it. It has the relation to the parietal of a buttress to an arch.

When great pressure is made on the top of the head, as when a heavy load is carried there, there must be a tendency to outward lateral pressure at the base of the dome of the cranium. This pressure is effectually resisted by the temporal bones acting as buttresses. The same thing is true, also, when a blow is inflicted on the top of the head. And if a blow be received at the side of the head, on the temporal bone, it is evident that the bones will not be so apt to be fractured and pressed inward upon the brain, as they would be, if they were united by suture.

54. Protection to the Brain.—You are now prepared to see, to what extent the brain is guarded against the effects of violence inflicted upon the head. These effects come either from fracture of the bones, or from concussion without fracture. In either case the *vibration* of the parts concerned is the cause of these effects. The guards of the brain defend it from injury, by lessening or diffusing this vibration. And it is to be observed, that when vibration passes from one texture to another, it loses some of its force in the change.

No two substances vibrate just alike; and when a vibration in one is communicated to another, it is modified, and is therefore lessened. Some substances modify and lessen vibrations communicated to them more than others do. If you apply these principles to the effects of violence on the head, you at once see that the brain would be much more apt to receive a dangerous shock from the vibration occasioned by a blow, if its coverings were condensed into one firm and thick layer of substance, than it is now. So also, if the

bones of the head were in one solid layer, instead of having two layers, or plates, with the spongy structure between, and the integuments were all consolidated into one thick substance, there would be much more liability to fracture than there is with the present arrangement.

Observe now how many, and how various are the textures, through which the vibration of a blow must pass, before it reaches the brain. Outside of the bone there is first the hair; next comes the skin; then there is the cellular membrane containing some fat; then a muscular coat; and lastly, the lining membrane over the surface of the bone. These various textures must deaden very much the force of a blow, and especially the outer cushion of hair, and those inner cushions, as we may call them, of fatty cellular membrane and of muscle. Then, when the vibration reaches the bone, it is lessened by the two plates with the intervening cells, and there is diffused largely among the many bones that unite with the one on which the force comes. Then as the shock goes into the brain, it is still farther lessened by the membranes which cover that organ. These greatly diminish the vibration, precisely as a coating of leather on the inside of a bell would deaden its vibration when produced by a blow upon the outside. With all these provisions the result is, that comparatively few of the blows received by the head do harm.

55. Protection at Particular Points.—There are some especial guards at particular points in the cranium, where there is much liability to exposure to violence. Thus, as the lower part of the frontal bone, where the eyebrows are, is especially exposed, the distance from the surface to the brain is made considerable by an intervening chamber in the bone, called the frontal sinus. This sinus, which varies much in size in different individuals, is lined with a membrane, and communicates with the nose. You can see that this arrangement is a great protection to the bone at that point. The outer plate could be broken, and the inner remain uninjured.

But the protection which this arrangement affords, is not

confined to that single point; it serves also to deaden the vibration of a blow received by any part of the forehead, or by the forehead as a whole. The side of the head, too, is peculiarly exposed to blows. And, therefore, the skull is peculiarly guarded at this point. Beside the overlapping of the temporal bone upon the parietal, to which allusion has been made, the parietal bone is made thicker at its lower part, where it is most liable to be struck, than it is in most of the other parts of it.

Then, too, the place of joining of the temporal and parietal bones is covered over by a thick muscle, the contractions of which you can feel if you press your fingers upon the temple while moving the lower jaw as in eating. This cushion of muscle is of great use in breaking the force of a blow received in that quarter.

56. Protection of Organs.—The cranium not only contains and protects the brain, but it at the same time serves various other purposes, and protects other important organs. The tender and delicate eye has there a bony socket with jutting prominences all around it, to guard it against violence. The exceedingly minute and complicated apparatus of the hearing is also carefully protected by the skull, and the most important part of it is furnished with winding and intricate apartments, halls of audience, in that part of the temporal bone which is so hard, that it is called the *petrous* or rock-like bone. To the bones of the cranium are attached in various ways, the fourteen bones of the face. All these, with the exception of the lower jaw, are immovable. The two principal of them are the upper jaw bone, and the cheek bone. The former makes with its mate of the other side the forward portion of the roof of the mouth, the palate bones making its rear portion ; and it furnishes the sockets for the teeth. It also at its upper part makes nearly the whole of the floor of the orbit of the eye.

The cheek-bone forms the outer lateral part of the socket of the eye, and sending back a process or projection to unite with one from the temporal bone, *c*, Fig. 6, forms

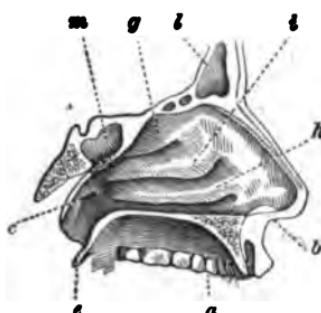
the *zygoma* or arch, inside of which the temporal muscle passes down to be fastened to the lower jaw. The bones of the nose make quite a complicated series of cavities, for the purpose of presenting, in the mucous membrane, which lines them, a large surface, over which the nerve of smell is expanded.

A representation of these cavities is given in Fig. 8; in which *a* is the mouth; *b*, the opening into the nostril; *d*, a part of the base of the skull; *c*, the communication of the nostril with the back of the throat; *e*, the curtain of the palate; *f*, the frontal sinus; *m*, another large sinus; *g*, *i*, *h*, spongy bones projecting into the cavity of the nostril. There is a large sinus, that is not seen in this figure, which lies over the teeth in the jaw-bone. The different sinuses are lined with the mucous membrane extending into them from the nose.

These, with the spongy bones, make a very large extent of surface in the cavities devoted to the sense of smell. The branches of the nerves of smell enter these cavities, to be distributed over thin walls, through many small openings in a bone in the roof of the nose, giving it a sieve-like appearance.

The lower jaw is a bone shaped something like a horse-shoe, with its ends turned considerably upward. It has two smooth projecting surfaces which articulate with two corresponding shallow cavities in the temporal bone. Its prominence at the lower part in front, the chin, is peculiar to man, there being no such prominence in any other animal. The lower jaw has sockets for the teeth, and it is so constructed, and is so provided with muscles, that these teeth can be brought to bear against the teeth of the upper jaw in cutting and grinding motions.

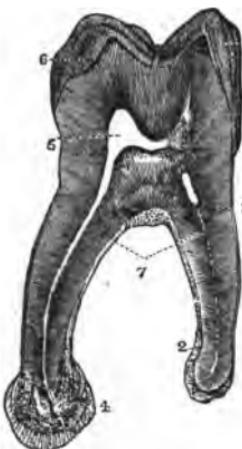
FIG. 8.



INNER BONES OF THE NOSE.

57. The Teeth.—The teeth are very nearly like the other bones in their structure, but differ from them in some particulars. Every tooth has in it three distinct structures, which differ in hardness, for reasons which will appear clear to you as we proceed. The *dentine* or ivory constitutes the body both of the tooth and of its fangs. In the body of the tooth there is a coating of that very hard substance, the *enamel*, over the whole surface of the ivory. This is thickest over the top of the tooth, and grows thinner on the sides till it is entirely gone where the gum begins. The ivory in the fangs has a coating of a very different character, called the *cementum*. It is not hard like the enamel. This arrangement is represented in Fig. 9. This is a tooth with two fangs or roots; 1, is the *enamel*; 3, the *dentine* or *ivory*; 2 and 7, the *cementum*; 4, an unnatural enlargement of the *cementum*, making an excrescence; 5, the cavity of the tooth supplied with blood-vessels and nerves which come through the channels that you see running up the middle of each fang.

FIG. 9.



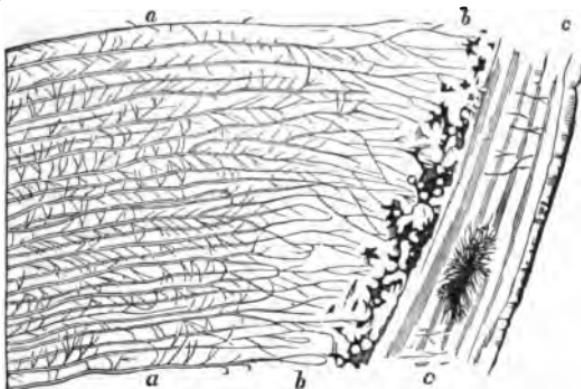
SECTION OF A TOOTH.

a, a, being the *dentine*, and *c, c*, the *cementum*, evidently a different structure.

58. Difference between Bones and Teeth.—A tooth differs from a common bone in one important particular—when once formed it is never altered in its size. A

bone grows with the growth of the other parts of the body ; but a tooth, when it first protrudes through the gum, is as large as it ever will be. The reason of this is, that so hard

FIG. 10.



a substance as enamel can not be made changeable as bone is. Its hardness is inconsistent with anything like circulation in it, and without circulation there can be no change.

If the enamel were not needed, and the teeth could be composed only of dentine, they could grow as other bones do. And if they could grow, one set of teeth might be made to answer the purpose. As it is, the second set are needed, because as the jaws grow, the first set are neither large enough in proportion to the size of the jaws, nor numerous enough to fill up the whole space. If the first set were to be the only set, when the jaws became of their full size, the teeth would be altogether too small, and would be quite separated from each other. Twenty small teeth (the number of the first set) in the jaws of an adult, in place of the thirty-two large teeth of the second set, would present a very odd appearance, besides being incapable of doing the service required of them.

59. Bones not belonging to the Natural Skeleton.—Under the lower jaw is a little bone, called from its resemblance to the Greek letter *v*, the *hyoid* or *u*-like bone. Its round end is towards the root of the tongue, and its

two free ends reach backward towards the spine. The larynx is suspended from it as from a frame, and the muscles that draw up this bone, draw up the larynx with it. It is one of the few bones in the body not directly connected with any other bone. The *patella*, or kneepan, is one of these bones. Also the four little bones in the ear, are not connected with any other bone.

60. *The Spine considered as a Single Piece.*

—Pass now to the bones of the trunk of the body. Let us first consider the spinal column, or the backbone, as it is called in common language, as if it were all one bone. In some respects it does act as one, although it is made up of twenty-four distinct bones. It is the great pillar of the body. As such, it has the head resting on its top, and it furnishes support for the walls of the chest, and for the muscles which make up the most of the walls of the abdomen. To it also are fastened the mass of intestines in the abdomen, and indeed to some extent all the viscera both of the abdomen and the thorax. Sustaining, therefore, so much weight in so many ways, it stands firmly planted on its great pedestal, the strong broad bone of the pelvis, the sacrum.

And this pedestal is supported, as before said, after the manner of a keystone, between the lighter spreading bones of the pelvis on either side. But while the spinal column acts as a strong and firmly supported pillar, it is necessary that it should be *flexible* for the different motions of the body. It is therefore composed of twenty-four bones called the *vertebræ*, so that, as in any considerable motion of the column as a whole, there is but little motion between any two of them, the motion does not interfere with its office as a firm pillar. It is most free in its uppermost part, the neck; considerably so in its lower part, the small of the back; and it is least free in that part to which the ribs are joined.

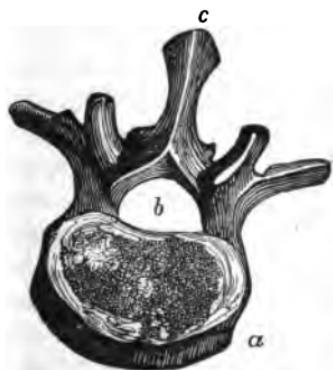
You readily see the reasons for this difference in motion in different parts of the column. For the varied motions of the head there is need of a free movement of the verte-

bræ. Then for the twisting and turning motions of the body, you have the free movement at the lower part of the column, which is easily provided for there, because there are attached to that portion of it nothing but parts that are pliable. It is not so with that portion of it that forms the supporting pillar of the framework of the chest. There is little motion here of the vertebræ, because the joining of the ribs to the column forbids it.

But besides serving as a firm pillar, and as a flexible chain, the spinal column also forms a canal or tube in which the spinal marrow, one of the most delicate and important organs in the body, is securely lodged. This canal extends through its whole length, and from the spinal marrow included in this canal, nerves pass out to all parts of the body.

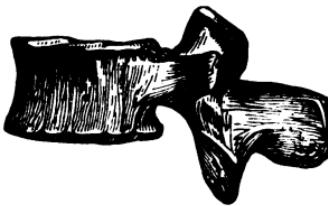
61. Vertebræ and their Union.—In Fig. 11, you see a representation of one of the vertebræ; *a*, being the

FIG. 11.



A VERTEBRA.

FIG. 12.



A SIDE VIEW OF A VERTEBRA.

body of the bone; *b*, the hole which forms this vertebra's part of the canal for the spinal marrow; and *c*, the spinous process. It is these spinous processes that make the row of projecting points seen down the length of the back. There are six other processes, only four of which you can see in the figure. Four of these processes serve to lock the

vertebra with its two adjoining ones above and below, which they do so strongly, that there can be no dislocation of them without a fracture. Fig. 12 gives a side view of a vertebra.

Strong ligaments bind these bones together, and there are very numerous muscles attached to the processes, so that this jagged column of bones is very thoroughly enveloped in softer substances.

FIG. 13.



SPINAL COLUMN.

62. Spinal Cord.—In Fig. 13, you see the whole spinal column with the sacrum on which it stands. It is laid open by a vertical section dividing it into two halves, so as to show the manner in which the bones form the tube that contains the spinal marrow. The darkly shaded strip through the length of the figure represents this tube. It extends, you see, down beyond the limits of the column itself through the sacrum. It is bounded in front by the bodies of the vertebræ represented as sawed through from front to rear, and by the spinous processes behind also sawed in the same way. In this canal you see there is a row of little openings, arranged just behind the bodies of the vertebræ. Through these openings, each of which is between two of the vertebræ, the nerves go out from the spinal marrow. The arrangement is such, that the nerves are very securely guarded against the hazard of pressure in the movements of the vertebræ upon each other.

63. Intervertebral Cartilages.—

You see also that there are spaces between the bodies of all the vertebræ. These are filled with cartilages, which vary in thickness in different parts of the column, from one-quarter to three-quarters of an inch, being thickest in the

lower part of the back, where the backward and forward motion of the vertebræ upon each other is the greatest.

Each cartilage is firmly fastened to the two vertebræ, between which it is situated, by the rough surface of the body of the bone which you see represented in Fig. 11. This arrangement of cartilages is an important provision for the motion of the spinal column. It contributes greatly to its flexibility. When you stoop forward, all the cartilages are compressed, and when you rise up they return to their usual size by their elasticity. And besides this, they serve to diminish any shock which might otherwise be transmitted through the column of bones to the head with too great force. There is another guard against the injurious transmission of shocks to the brain, in the *shape* of the spinal column, the twenty-four bones being arranged, not in a straight line, but in a double curve.

The vibration, communicated upward through the spinal column, is thus not only lessened by the elasticity of the cartilages, but is also distributed in different directions by the curved arrangement of the bones. If the column had been made straight, the head would be subject to frequent jars in the movements of the body, which would be disagreeable and often injurious.

64. Different Objects in the Arrangement of the Spinal Column.—You have thus seen how three different objects, apparently incompatible with each other, are accomplished in the arrangement of the spinal column. To put twenty-four bones together in such a way, that they shall form a strong firm pillar for the whole frame, and yet they shall make a column or chain flexible enough for the various motions of the trunk of the body, and at the same time provide, in this column, a secure canal for the rod of nervous matter which moves all the muscles of the body, is to produce a piece of mechanism which far transcends anything that has ever been contrived by the ingenuity of man.

65. Arrangement of the First and Second Vertebræ.—There remains to be noticed one especial contrivance in the spinal column. It is at its summit, and

is for the purpose of providing for the free motions of the head in various directions, and at the same time securing the spinal marrow at that part, from all hazard of pressure from these motions.

These two objects are accomplished in this way. The head in moving backward and forward rocks on two smooth surfaces on the first vertebra. But when the head moves to the right and left, this first vertebra moves along with the head on the second vertebra. And there is a tooth-like process that projects up from the second vertebra inside of the first, around which this rotary motion is performed. In Fig. 14 is represented the first vertebra. J, J, are the two surfaces on which the head rests, and rocks backward and forward. A is the opening for the spinal marrow. L is the strong ligament which confines the tooth-like process that projects upward from the second vertebra. In Fig. 15 is the second vertebra. P is the tooth-like process, around which the first vertebra rotates, carrying the skull with it. You see it is smaller at its root than at its top. This smaller part is bound firmly by the ligament in the first vertebra. It is shaped thus to prevent its slipping out from the ligament. J, J, are the two surfaces on which the first vertebra moves as it rotates around the tooth-like process.

Fig. 16 shows the two bones together, the tooth-like process being confined in the ring of the upper bone. Special pains are taken to make this arrangement secure, that the process may not be in danger of pressing upon the spinal marrow at this important point. It is thus that the lateral rotary motion of the head and the forward and backward motion are secured by two joints, just as is done in the mounting of a telescope. The difference between the two cases is, that in the mounting of the telescope there are no difficulties to overcome, while in arranging the mounting of the head, as we may term it, a peculiar contrivance and a nice adjustment are needed to prevent injury of a very important organ. It is a wonderful contrivance, by which so much and so varied motion can be effected in the very walls that contain the soft and delicate spinal marrow, without

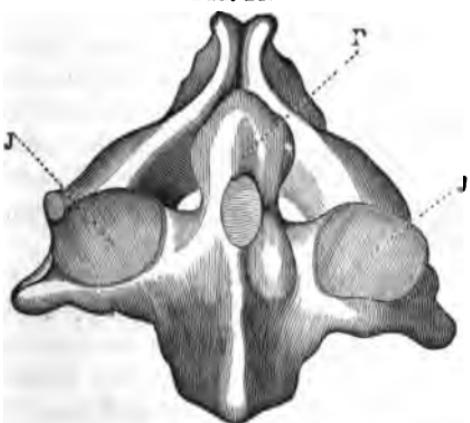
injuring it. You will fully appreciate this, if you observe the extent and variety of the motions of the head and neck executed chiefly with the two bones previously described.

FIG. 14



FIRST VERTEBRA.

FIG. 15.



SECOND VERTEBRA.

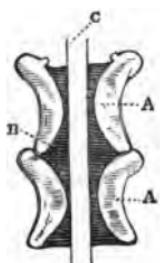
FIG. 16.

First and Second
VERTEBRAE TOGETHER.

66. Vertebrae of the Bird.—In the neck of birds there is a contrivance of a different character, for the arrangement which answers for the motions required by man, obviously could not secure the very free motions which the bird executes with its neck. As the bird bends its neck at such abrupt angles in all directions, a peculiar arrangement

of the vertebræ is necessary, to prevent the spinal marrow from being pressed upon.

FIG. 17.



SPINAL COLUMN
in Birds.

The arrangement is a simple, but effectual one. This can be made plain to you by the rough diagram in Fig. 17. A, A, are two of the vertebra of the neck laid open. B is the spinal canal, and C is the spinal marrow. You observe that each vertebra is larger at its ends than in the middle, allowing at the joinings of the bones, where the motion is, a considerable space between the bone and the spinal cord.

Now if each of these bones was of equal size throughout, and the spinal marrow filled up the canal, you can readily see that when any two of these were much bent upon each other, there would be pressure upon the spinal cord; and pressure would produce palsy, and often destroy life. But with the simple arrangement above described, free motion, almost to a right-angle in some directions, can be executed without pressing on the cord. And besides this, you can see that the cord by this arrangement will not be bent at an angle, as the vertebræ are, but in a curve, for the spaces in the spinal canal at the joinings allow of a lateral movement of the spinal marrow at these points.

67. Vertebræ of Quadrupeds.—In quadrupeds, as they have their heads suspended, instead of being supported, as in man, upon a column of bones, the spinous processes in the neck are very large, and project much, for the attachment of strong muscles which hold up the head and move it. There is also attached to these processes, a very stout fibrous ligament, commonly called the *paxy-waxy*, to assist in sustaining the head.

68. Vertebræ of Fishes.—In fishes the spinal column is so arranged as to give it great flexibility. In Fig. 18 is represented one of the vertebræ of a fish. If you compare it with a human vertebra, as seen in Fig. 11, you will see that it differs very widely from it. It has no transverse or side processes.

While the human vertebra has one *spinous* process that projects behind, this has two, *f*, *f*, one in front and one in the rear, or rather, according to the usual position of the fish, one above and one below. The body of the vertebra has a cup-like cavity on each side towards its neighboring vertebra. When, therefore, two of these vertebræ are joined together, their two cup-like cavities make one cavity of the shape of a double cone, as seen in Fig. 19.

This is a representation of a section of a portion of the spine of a fish. The division is made so as to cut the vertebræ into two halves, and thus show these cavities. Each one of these contains a sac which is filled with a gelatinous fluid. This arrangement, which secures very great flexibility of the spinal column, you can examine at any time when you have fish on the table. The long spinous processes make the broad framework of the animal, to which its muscles are attached.

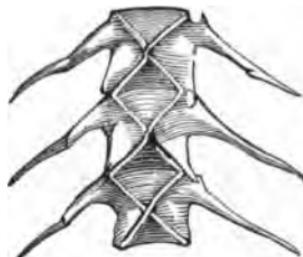
69. Vertebræ of Reptiles.

—In reptiles there is still greater flexibility of the spine than in fishes. This is secured in two ways, by the great number of the vertebræ, and by a peculiar arrangement of them. There are three hundred and four vertebræ in the boa-constrictor, over three hundred in the common ringed-snake, and over two hundred in the rattle-snake. The articulations of the vertebræ in reptiles are with a ball-and-socket arrangement. The forward part of each vertebra has a deep cup-like depression, in which plays a round smooth ball from the back part of the next vertebra. And as these joints are firmly bound together by ligaments, the spinal column is very strong as well as flexible. In the

FIG. 18.

VERTEBRA
of a Fish.

FIG. 19.



SPINAL COLUMN OF A FISH.

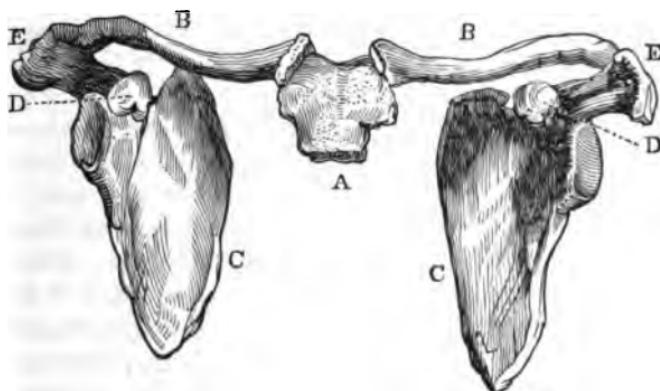
gracefully flexible neck of the giraffe we have the same ball-and-socket articulations of the vertebræ.

70. Bones of the Thorax.—The breastbone, which is flat and of simple form in man, is much larger and less simple in its form in some animals. In flying birds it is not only broader, but it has a keel-shaped projection for the attachment of the large muscles used in flight. The *clavicle*, *g*, Fig. 5 (so called from its resemblance to a key, and commonly called the collar-bone), is attached at one end to the top of the breastbone, and at the other unites with a process of the *scapula*, or shoulder-blade at the top of the shoulder-joint. It is a prop to the shoulder, pressing it outward; and accordingly it is large in those animals the movements of whose superior extremities tend to bring the shoulders toward each other, while it is very slender, or absent even, in those the tendency of whose movements is to keep the shoulders apart. Thus in birds the drawing down of the wings by the strong muscles would bring the shoulders toward each other, were this not prevented by stout clavicles. Sometimes a second bone is added for the same purpose.

But in the horse and other similar animals, the pressure of the body downwards between the shoulders tends to separate them, and here we find the clavicle deficient because it is not needed. The *scapula*, or shoulder-blade, is a thin bone with a stout raised spine or ridge running across it, and forming by its end the top of the shoulder-joint. It is situated differently from any other bone in the body. It is imbedded in muscles and has a very free motion. The design of this attachment is to give freedom of motion to the arm. The scapula is directly connected with the skeleton only by its union with the clavicle.

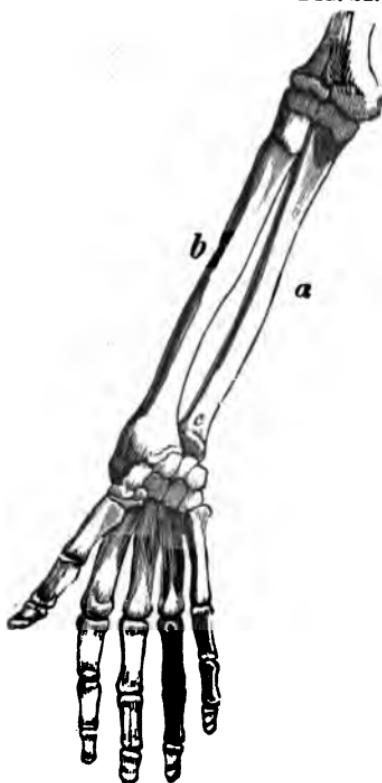
In Fig. 20 you see the arrangement of the clavicle, scapula, and breastbone. *C, C*, are the scapulæ or shoulder-blades. *A*, is the upper part of the breastbone. *B, B*, are the clavicles fastened to the breastbone at one end, and to the shoulder-blade at the other end at *E*, which is a process of the shoulder-blade, making the projecting top of the shoulder-

FIG. 20.



THE COLLAR-BONES AND SHOULDER-BLADES.

FIG. 21.



joint. D, is another process of the shoulder which serves for the attachment of muscles and ligaments. It is called the *coracoid* process, from its resemblance to the beak of a crow.

• **71. Bones of the Upper Extremities.**—The upper extremity is divided into three parts, the arm, the forearm, and the hand. The arm has but one long bone, the *humerus*, *i*, Fig. 5. This has a round head which moves in a shallow cup formed by the shoulder-blade. The shallowness of the socket is the cause of the frequency of dislocations of the shoulder. But if there were a deep socket like that which receives the head of the thigh-bone, the arm could not have anything like its present freedom of motion. Such an arrangement would involve too much of a sacrifice of necessary uses for the sake of security. At its lower part the humerus makes a hinge-joint with the forearm.

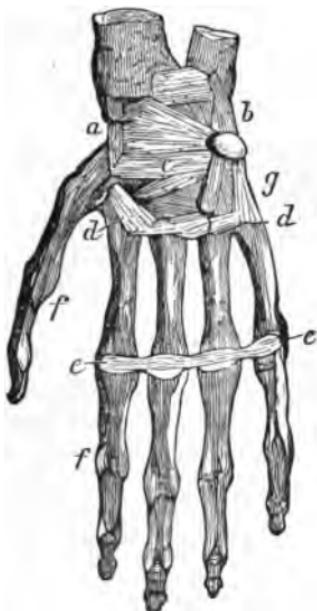
The forearm has two bones, the *radius*, *b*, Fig. 21, and the *ulna*, *a*. The peculiar arrangement of these two bones is worthy of notice. The hinge-like motion of the forearm upon the arm is performed by the *ulna* alone. This bone has a beak-like process, which works over a smooth round surface at the end of the humerus. It is the outside of this process which you feel at the point of the elbow. The other bone, the *radius*, has nothing to do with this motion. This only rolls on the ulna in the rotary motions of the forearm. But at the other end of these bones, at the wrist, the arrangement is reversed. Here, it is the radius on which the hand moves in a hinge-like manner, while the ulna at *c* rolls on the radius, as the radius does on the ulna at the elbow.

You can readily see that as the radius rolls on the ulna at the elbow, and the ulna on the radius at the wrist, a very free rotary motion of the forearm is provided for. The combination of this motion with the motions at the wrist, the elbow, and the shoulder, secures that almost endless variety of movement, which is so striking a peculiarity of the upper extremity, as compared with the lower.

The hand is divided into three parts, the *carpus*, *p*, Fig. 5, composed of eight small bones, the *metacarpus*, *q*, composed

of bones which are like the bones of the *fingers*, r. The eight bones of the carpus are firmly packed together, but they have a slight motion upon each other, and this, together with the motion of the metacarpal bones, makes the hand a more easy, light, and springy instrument than it would be, if these bones were all consolidated into one. The metacarpal bones are the framework of the flat part of the hand, and to them are joined the first row of the bones of the fingers. The metacarpal bone of the thumb has a very free motion upon the carpus, differing in this respect altogether from the metacarpal bones in the body of the hand. The bones in the wrist and hand are bound together by very strong ligaments. Those which are seen in the palm of the hand are represented in Fig. 22. Those which you see at *a*, *b*, and *c* bind the small bones of the wrist to-

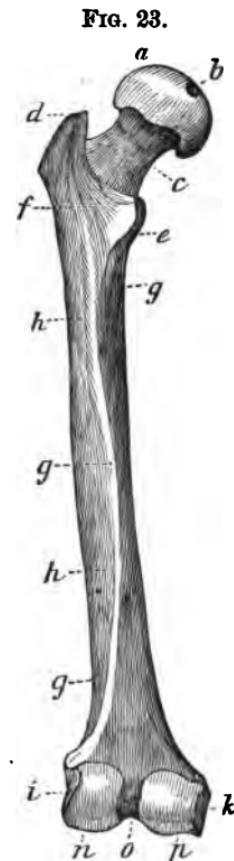
FIG. 22.



gether, and also tie them strongly to the bones of the forearm, the ends of which you see in the Figure.

The bone at *b*, to which so many of these ligaments are attached, is the prominent bone which you feel at the beginning of the palm of the hand on the side towards the body. The ligament *g* connects this bone with the metacarpal bone of the little finger. At *d*, *d*, are ligaments which running across the hand bind the metacarpal bones together at their beginning. At *e*, *e*, are similar ligaments, where the bones of the fingers join them. The bones of the fingers and thumb are strongly held together by lateral ligaments, as seen at *f*, *f*. The various ligaments of the wrist and hand permit a slight motion between the bones; and thus the hand has freedom and ease in its motions while it is also a very strong and firm instrument.

72. Bones of the Lower Extremities.—The lower extremities have some resemblance to the upper in their structure and arrangement, but differ from them in some important respects. Here firmness is the chief object, while freedom of motion is the great thing to be secured in the upper extremities. The lower extremities are chiefly for locomotion, but the upper are fitted for a variety of purposes. The body is supported upon the lower extremities, and therefore, the thigh-bones have sockets in the broad flaring bones of the pelvis *m* and *l*, Fig. 5. In Fig. 23, is represented a rear view of the thigh-bone. Its head, *a*, is round, and fits into a deep socket in the pelvis.



At *b* is a depression in which one end of a stout short ligament is fastened, its other end being attached to the

bottom of the socket. At *c* is the neck of the bone; at *d*

and *e* are two projections to which are attached large muscles to move the limb. Along the shaft of the bone, *g*, there is a rough ridge, *h*, to which muscles are fastened; *i* and *k* are two smooth surfaces for articulation with the leg below. At *t*, Fig. 5, is the bone called the *patella* or kneepan, which answers as a defence to the joint, and at the same time affords a mechanical advantage to the muscles which throw the leg forward.

These muscles are fastened to the upper part of the patella, and then a connection is formed by a strong tendon between its lower part and the large bone of the leg. You see at once that the leg can be thrown forward with more force by this arrangement, than it could be if the tendon of the muscles passed over the front of the joint without any patella.

This will be referred to again in the Chapter on the Muscles. The leg has two bones, *v* and *u*, Fig. 5; but unlike those of the forearm they are constructed and arranged for strength, and not for freedom of motion. The foot, like the hand, is divided into three parts. The *tarsus*, *a*, Fig. 24, is that part of the foot which extends from the heel to the middle of the foot. It is composed of seven bones, the largest of which makes the body of the heel. The *metatarsus*, *b*, has five long bones reaching from the tarsus to the

FIG. 24



toes. The toes, *c*, have fourteen bones. The object of having so many bones in the body of the foot is to give a certain springiness to it, which guards against shocks, and facilitates motion. Its arched form also tends to secure the

same object. In every movement of the foot there is a slight motion between all these bones.

Thus in walking, when the foot first touches the ground, it does so at the heel, as represented in Fig. 24. Then as the body moves forward, the fore-part of the foot is brought down, the weight of the body at length pressing upon the ground at the ball of the foot, *b*. In executing this movement, elasticity is given to the tread of the foot by the very slight motion which occurs between these many bones. If the body of the foot were all one bone it would manifestly be a very stiff and awkward affair, and ease and grace in walking would be an impossibility. With such a foot we should not walk much better than one does with a wooden leg.

73. Synovial Membrane.—Before leaving the subject of the bones, your attention is called to the provision

which is made for the easy movement of their joints. The ends of the bones are tipped with cartilage, so as to afford a firm but smooth surface for the motion of the one bone upon the other. Besides this provision, the ends of every two bones that move upon each other are lined with a membrane, so arranged as to make a blind sac.

This is illustrated in Fig. 25, in which *a* and *b* are the ends of two bones, the sac, *c*, lying between them represented here as detached from the bone, in order that the arrangement may be clear to you. It is as if a small bladder were introduced between the two ends of the bones, and were fastened all over the surfaces that press together.

The inside of this sac is kept lubricated with a bland fluid resembling the white of egg, so that the joint may work easily. This fluid is secreted by the membrane itself, and the moving machinery of the human system may therefore be said to oil its own joints.

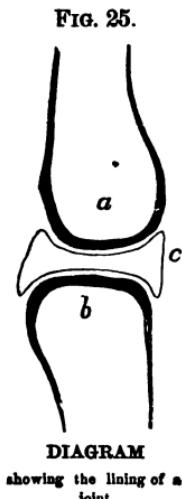


DIAGRAM
showing the lining of a joint.

SKELETON—BONES, JOINTS, LIGAMENTS.

BONES.	COMPOSITION.	
	CHARACTERISTICS.	
USES.	CHARACTERISTICS.	JOINTS.
CLASSES AS TO FORM.	USES.	JOINTS.
NUMBER, PLACE, AND NAMES.	CLASSES AS TO FORM.	LIGAMENTS.

In the knee-joint, the broad surfaces of which are subjected to so much pressure, there are two flat pieces of cartilage loose in the joint, which operate like friction-wheels in lessening the friction. There is a similar provision in the articulation of the lower jaw. This member does so much work in talking, and such heavy work in mastication, that each of its joints has a movable cartilage for the diminution of friction. Sometimes when the lubricating fluid is deficient, or becomes too thick, a disagreeable crackling noise is produced by these cartilages in the motions of the jaw.

CHAPTER V.

THE MUSCLES.

74. Structure of Muscles.—Muscular substance is what is commonly called the *lean meat*. It is of various colors in different animals, or in the same animal at different periods of life.

All motion in animals is produced by muscles. They act by contracting or shortening the fibrils of which they are composed. Commonly there are tendons united with the muscles. These tendons are composed of strong white fibres, and have no power of contraction themselves. They serve merely as the cords by which the contracting muscles move the bones and other parts.

75. Each Fibril of a Muscle Supplied with a Nerve.—Each fibril of which the muscle is composed, is a chain of cells, and it is the shortening of all these chains of cells in a muscle that produces its contraction. The action of a muscle is dependent upon the nerves. Each fibril has a nervous fibril or tubulus, by which its connection with the brain or spinal marrow is established. And each fibril is in this respect probably wholly separate from every other

fibril. When, therefore, the mind wills that a certain motion shall be performed, an impression is sent to each fibril of every muscle engaged in that motion, through the tubulus devoted to that fibril. When the action is a very complex one, calling into operation many muscles, a multitude of these impressions are communicated through a multitude of distinct channels or tubuli. The individual is not at all conscious of the compound nature of muscular action, and he knows nothing of the muscles which produce any particular movement, unless he has studied anatomy and physiology. He wills the movement to take place, and at once the requisite impressions are sent along the appropriate channels or tubuli to their destination.

These impressions must differ in degree or intensity in producing different amounts of motion; and they must differ in some cases in different parts of the same muscle, as some fibres are put in motion while others are not, or as some act with more force than others.

76. Tendons.—Muscles commonly end in tendons, which, as they are white and shining, are quite in contrast with the red muscular fibres. The tendons have in themselves no power of contraction, but are mere passive cords. They have the same relation to the muscles that ropes have to the men that pull them. They are of various shapes, according to circumstances. Long and slender tendons may be seen on the back of the hand in thin persons, the muscles that pull them being in the full arm above.

The tendons are not bounded by a distinct line where they join the muscles, but tendinous and muscular fibres intertwine, so that they appear to run insensibly into each other. Tendinous fibres also mingle in the same way with the fibres of bone, making so strong an union, that a great force exerted in pulling on the tendon will sooner effect a rupture of the tendon or the bone, than a separation of the connection between them.

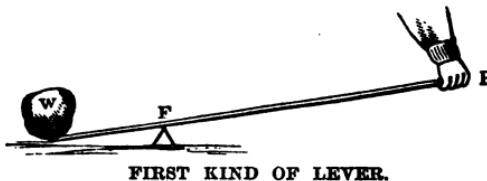
77. Strength and Size of Tendons.—The tendons are very strong, being made of very condensed fibrous substance. The tendon of a muscle is, therefore, much

smaller than the muscle itself. This is a circumstance of much importance in the arrangement of the moving apparatus of our frames. The bulky muscles and the slender tendons are so arranged, for example, in the limbs, as to give them both freedom of motion and beauty of form. The muscles that move the fingers help to make up the full part of the arm, while their slender tendons occupy but little space as they play over the bones of the wrist. If there were no tendons, and the muscles were extended to the parts which they move, the hand would be a large cumbrous mass, instead of the light and agile thing that it is now.

78. Action of Muscles.—In the action of the muscles upon the bones, we have examples of the three kinds of levers treated of in natural philosophy.

79. First Kind of Lever.—The first kind of lever has the fulcrum between the weight and the power, as represented in Fig. 26. F is the fulcrum, W the weight, and

FIG. 26.



FIRST KIND OF LEVER.

P the power. You have examples of this lever, in the common pump-handle, the beam of a pair of scales, the crowbar, as commonly used, scissors, &c. You have an example of this form of lever in the human body, in the action of the muscles in moving the head back and forth on the top of the spinal column.

In this case, when the head is moved forward, the top of the spine is the fulcrum, the weight to be moved is the back of the head, and the power is the contraction of the muscles that bow the head forward. When the head is bent backward, the power is the contraction of the muscles behind, and the weight is the front part of the head. The muscles that move the head backward are stronger than those that

move it forward. It is necessary that this should be so, for there is more of the head in front of the point of support or fulcrum than there is behind it. Hence, when sleep relaxes the muscles, if we are sitting up the head falls forward.

80. Second Kind of Lever.—In the second kind of lever the weight is between the fulcrum and the power, as represented in Fig. 27. The common wheelbarrow is an example of this form of lever. You have an example of it in the body in the raising of the heel from the ground

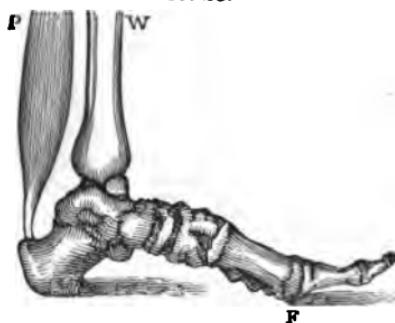
FIG. 27.



SECOND KIND OF LEVER.

in walking. In doing this, the weight to be raised is the whole body, the foot being the lever, and the forward part of the foot being the fulcrum. This will be made clear by Fig. 28. W is the large bone of the leg sustaining the

FIG. 28.



weight of the body; F, is the fulcrum, the forward part of the foot that presses on the ground as the heel is raised; and P, is the power at the end of the lever, the large muscle in the calf of the leg, that raises the heel.

81. Third Kind of Lever.—In the third form of lever the power is between the weight and the fulcrum. A common example of this is seen in the raising of a ladder. The fixed foot of the ladder is the fulcrum, the ladder itself is the weight, and the power is applied as far from the fulcrum as it can be. Fig. 29 represents a lever of this kind.

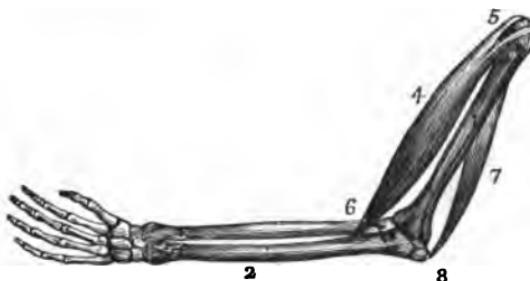
FIG. 29.



THIRD KIND OF LEVER.

This form of lever is more frequently used than the other forms in the human body. We have an example of it in bending the forearm upon the arm as seen in Fig. 30, in which 1 is the bone of the arm; 2, the bones of the forearm; 4, the muscle which bends the forearm upon the arm; 5, its double-headed attachment above; and 6, its attachment to

FIG. 30.



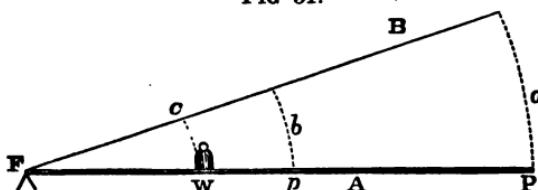
the radius, one of the bones of the forearm. In this case the fulcrum is at 8, the joint of the elbow, the weight is the hand with whatever it holds, and the power is applied at the point where the tendon is fastened to the radius, that is, as in the case of the ladder, between the fulcrum and the weight. The muscle which straightens the forearm upon the arm is represented at 7.

82. Time and Power.—In the management of the three kinds of levers there are two different objects aimed at, under different circumstances. One object is to move a great weight with a small power. Here quickness is not aimed at, but the weight is moved slowly. The other object is to move the weight quickly, an object inconsistent with the moving of any very heavy weight. When the object is to move a heavy weight slowly, the lever is so managed as to get a good purchase, as it is expressed.

Thus in the case of the lever of the second kind, Fig. 27, if the weight be a heavy one, the power is commonly applied at some distance from the weight. The nearer the power is to the weight, the greater must it be to move the weight. The smaller the power, the further must it be from the weight.

But though a small power, if at a distance from the weight, answers to raise it, yet in this case the power must move through a considerable space to move the weight but little; while to raise the weight to the same height, a power nearer to it passes through but little space. This will be made clear by Fig. 31. F is the fulcrum, and W the weight. If the lever, A, be raised to the line B, the dotted lines will show the different spaces which the power passes through, according to its distance from the weight. If the power be at P, it passes through the space indicated by the dotted line

FIG. 31.



a in moving the weight W to c. But if it be at p, it passes through a much shorter space, b, in raising the weight to the same height. The more important, therefore, in this form of lever, quickness of movement is, the nearer to the weight is the power applied.

Let us look at the application of these principles to the example of this kind of lever, which was cited from the human body, represented in Fig. 28, the raising of the weight of the body on the foot in walking. The power is here applied quite near to the weight, for quickness in raising the heel in walking and running is of great importance. By having the heel project farther behind, the muscle could be attached farther from the weight, and thus act with more power. But there would in this case be a sacrifice of quickness of movement, and besides this, the lengthened heel would present a very awkward and ugly appearance.

But it is in examples of levers of the *third* kind that we find these principles best illustrated. This form of lever is much more often used in the mechanism of the muscles than the other forms. Refer to the example given of this lever in the action of the biceps muscle in bending the forearm, as shown in Fig. 30. In this case it is of much more importance to move small weights quickly, than to move heavy ones slowly. Therefore the power is applied quite near to the fulcrum. The tendon of the biceps, as you see, is fastened to the main bone of the forearm near the fulcrum, the elbow. The point where the power is applied would pass through but little space, in moving a weight through a considerable one. The lower jaw, in its upward motion, is a lever of the same kind. In this case, force, rather than quickness, is required in breaking and grinding the food. Here, therefore, the power, the action of the muscle, is applied farther from the fulcrum than in the case of the biceps muscle of the arm, and nearer to the weight to be moved, or the point where the resistance is which is to be overcome. It is applied also in a different direction—a point which will be considered in another connection.

The muscles which move the lower jaw upward can be seen in Fig. 32. One is the large spreading muscle *b*, the swelling of which, in its contraction, we can feel, if we place the fingers on the temple while moving the lower jaw upward. The other is the short strong muscle *c*, the front

edge of which is so far forward, that one-third at least of the lower jaw-bone is embraced by this muscle.

Now, if you compare this bone as a lever, with the forearm as acted upon by the biceps, you will at once see that the

FIG. 32.



MUSCLES OF FACE AND NECK.

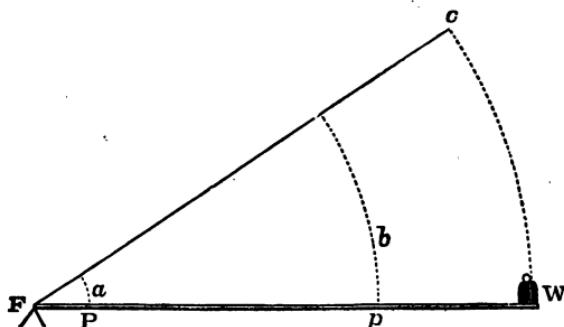
power is applied much nearer to the weight, or the resistance to be overcome, in the case of the jaw, than in the case of the arm. It is so even when the resistance to be overcome is at the front teeth; and it is much more so when the resistance is at the back part of the mouth, as when we are grinding our food. Here, indeed, a portion of the muscular force is brought to bear upon the resistance in a direct line. It is not merely because the back teeth are stronger than the front ones, but also because the power is nearer the resistance, that we can crack a nut more easily with the back, than we can with the front teeth.

83. Mechanical Disadvantage.—It is clear that the biceps muscle acts, as it is expressed, at a mechanical

disadvantage, if we regard mere power or force, and leave out of view quickness of motion. If it were inserted further down on the forearm, nearer the hand, it could raise much greater weights than it now can. A similar statement can be made of most of the other muscles of the body.

But force is sacrificed for the sake of quickness in most cases, because the latter is more important. In the few cases in which force is the more important, as in the case just cited of the lower jaw, the reverse arrangement is provided. This gain in quickness can be illustrated by Fig. 33. F being the fulcrum, the power in raising the weight, W,

FIG. 33.

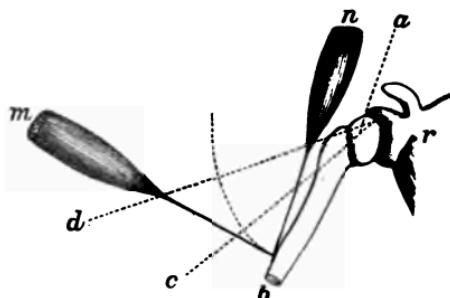


to *c*, if acting at *P*, passes through the space indicated by the dotted line *a*. But if it act at *p*, it will pass through all the space *b*, and of course raise the weight more slowly than when acting at *P*.

Most of the muscles work at a mechanical disadvantage in another way. Observe the direction in which the muscle acts on the bone to be moved. This is seldom at right angles, and therefore a considerable part of the force exerted is lost. This can be made clear by Fig. 34. Let *b* represent the bone of the arm, and *r* its fulcrum, or point of support in the shoulder. You readily see that if the bone be acted on by a muscle, *m*, at right-angles to it, it will require less force to move it to a given point than would be required if the same muscle were placed in the position

represented by *n*. For the muscle *n*, acting obliquely on the bone, would expend a part of its force in pressing the end of the bone upward against the socket of the joint at *r*.

FIG. 34.



But in this case also, what is lost in power is gained in quickness of movement. This can be shown by the figure. We will suppose that the muscle contracts or shortens itself half of the length of the tendon. If the muscle were placed as at *m*, the bone would be carried to the line *a*, *c*. But if the muscle be placed as at *n*, the same degree of contraction would raise the bone to the line *a*, *d*, the point of the bone where the tendon of the muscle is attached moving in the curved line as marked.

It, of course, requires much more power for the obliquely placed muscle, *n*, to raise the bone to the line *a*, *d*, than for the muscle *m*, to raise it to *a*, *c*; and therefore a much larger muscle is needed than there would be if it acted at right-angles to the bone as at *m*. And the muscle which raises the arm at the shoulder, acting as it does at so great disadvantage, is a very large muscle. The muscle, *n*, in the figure, represents only the line of its action, and not at all its shape. If you observe the various motions of the arm in which this muscle has a part, you will appreciate the necessity of so arranging it as to secure quickness of movement. This was the chief object to be aimed at in its arrangement; and the second and less important object, power, is secured, so far as it is needed, by simply making the muscle a large one.

84. Plan by which the Mechanical Disadvantage is Overcome.—The mechanical disadvantage,

which was noticed as resulting from the oblique action of the muscles, is in part obviated by a very simple contrivance. It is done by making the tendon of the muscle work over an enlargement of the bones at the joints.

FIG. 35.

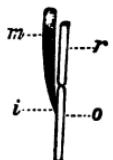


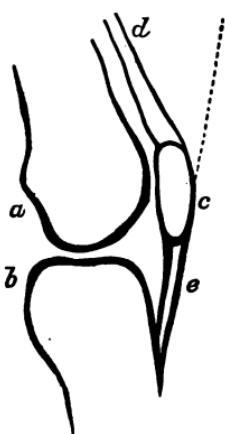
FIG. 36.



The operation of this contrivance can be made clear by Figs. 35 and 36. Let *r* and *o* (Fig. 35) be the two bones of a joint, and let the muscle *m* be attached to the bone *o* at *i*. As it contracts, almost all its force will be spent in drawing the bone *o* upward against the bone *r*, because it acts almost entirely in a line with the bones. But let the ends of the bones be enlarged as in Fig. 36, and you see that the direction of the tendon of the muscle *m* is so changed where it is attached to the bone, that the muscle can now very easily make the lower bone turn upon the upper.

The enlargement then of the bones at the joints, which

FIG. 37.



is needed to give the requisite extent of surface for working them, answers also another good purpose in thus altering the direction of force in the muscles. In the case of the knee-joint there is an additional contrivance for making this change of direction still greater. A movable bone, the patella or kneepan, besides acting as a protection to the joint, effects also the purpose referred to.

The manner in which it does this can be made plain by Fig. 37, in which *a* represents the end of the thigh-bone; *b*, the end of the large bone of the leg articulating with it;

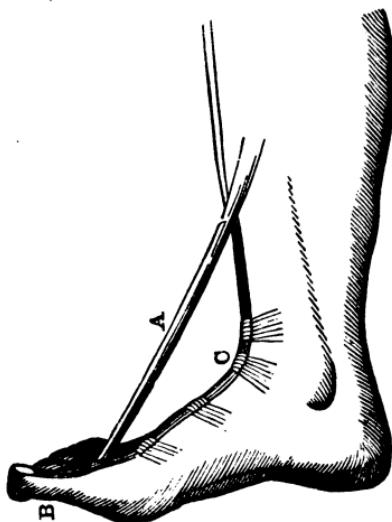
c, the patella; *d*, the large tendon which comes from the muscle above, and is fixed into the patella; and *e*, the ten-

don which goes from the patella to the large bone of the leg below. The dotted line shows how much the direction of the force of the muscle is changed by this arrangement. The movement performed by this muscle is throwing the leg and foot forward, which it is by the above arrangement of the patella enabled to do with great ease in walking, and with great force in the act of kicking.

85. The Pulley.—The pulley is used in the arrangement of the muscles, though by no means so often as the lever. It serves, whenever it is used, to change the direction of the force.

At the wrist and the ankle there are broad ligaments which bind down the tendons of the muscles, and sustain to them the relation of pulleys. If it were not for these ligaments the tendons at these joints would fly out continually when the muscles are in action, making projecting cords under the skin. And if the skin were removed, the tendons would be in a position similar to that represented

FIG. 38.

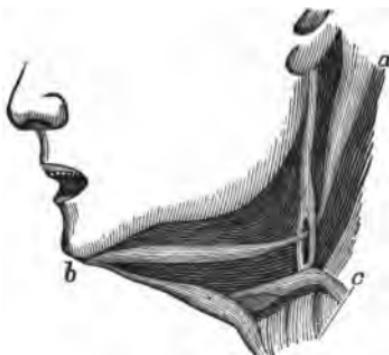


at A, in Fig. 38. In this Figure, C is a tendon of the great toe in its position as bound down by ligaments.

Now if the muscle were in the position represented by A, it is plain that it would act at a greater mechanical advantage than in the position C; but the toe would not be moved so quickly; and besides, if the tendons projected in this way, the foot would be a very cumbrous piece of machinery, compared with what it is now, with the tendons bound down around the slender ankle. So that both beauty and use are secured by the arrangement.

There is a beautiful application of the pulley in the case of the muscle that draws down the lower jaw, called the *digastric* muscle. It is represented in Fig. 39, in which *a* is one end of the muscle attached behind the ear, and *b* is the other end attached to the inside of the lower part of the chin.

FIG. 39.



DIGASTRIC MUSCLE.

It is muscular at the two ends, and tendinous in its middle part. This middle part runs through a loop or ring in a small muscle as represented in the Figure. This little muscle is fastened above to a small process of bone under the ear, and below to the hyoid, or U-shaped bone, *c*, which is situated just above the larynx. Now when the jaw is to be drawn down, the two fleshy ends of the *digastric* muscle contract, and the middle tendinous part works in the ring provided in the little muscle. This muscle is so slender, that its loop is of itself hardly strong enough, as we should

suppose, for the tendon of so large a muscle as the digastric to work in. And we accordingly find that there is an additional security in a strong ligament, which fastens the tendon of the digastric muscle to the hyoid bone.

This ligament (which is not represented in the figure, because it would confuse your view of the pulley-action of the parts) is sufficiently long to allow of all the freedom of motion necessary to drawing the jaw downward. You see at once that one object of this arrangement of the digastric muscle is to secure beauty of form in the neck. A muscle extending from the top of the chest to the chin in a straight direction would very effectually draw down the lower jaw, but it would be a great deformity. This is avoided by the pulley-arrangement of the digastric muscle.

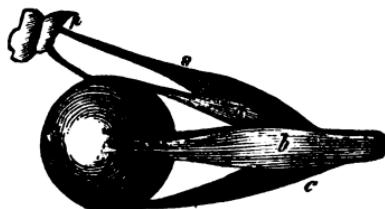
But this muscle answers another purpose besides drawing down the jaw. If, while the jaw be held fast by muscles which draw it upward, the digastric contracts, it will draw up, as you can readily see by the Figure, the hyoid bone, *c*, and with it, of course, the larynx which is attached to it. Now precisely this set of motions occurs when we swallow.

The mouth is shut by the drawing up of the jaw, and then the contraction of the digastric muscle draws up the larynx, as you can perceive if you place your fingers on the larynx, or Adam's apple, as it is called, when you perform the act of swallowing. The little muscle in which the loop is, renders some assistance to the digastric in thus drawing up the hyoid bone and the larynx, as you can see by the Figure.

86. Muscles of the Eye.—There are six muscles that move the eye-ball. Five of them are represented in Fig. 40. There are four straight muscles, three of which are marked *a*, *b*, *c*; the fourth is behind *b*, only the upper edge of it being seen in the Figure. These muscles are, at their origin in the back part of the socket of the eye, arranged round the optic nerve, and passing forward, are attached to the sclerotic coat, the firm white coat of the eye. The two lateral muscles, *b* and its opposite, move the eye to the one side and the other, and the two muscles, *a* and *c*, perform the up and down motions.

But there are certain oblique rolling motions of the eyeball which can not be executed by these straight muscles. For these motions two muscles are provided, one of which has a pulley-arrangement, as represented in the Figure.

FIG. 40.



This muscle, *s*, has a long tendon which passes through a ring of cartilage in the roof of the socket, and then turning back is fastened as you see to the upper part of the eyeball. This muscle is under the direction of one nerve alone.

It is an involuntary muscle which performs the insensible rolling motions of the eyeball, and like the other involuntary muscles of the body, is at work while we are asleep, as well as when we are awake. It is the muscle which rolls the eye about tremulously when it is open in the insensible state sometimes produced by disease.

87. Opposing Muscles.—Every muscle performing a motion has its opposing muscle or muscles, which perform the opposite motion. In the case of any two opposing muscles the one must be in some measure relaxed while the other is in action. Thus in alternately bending the elbow, and straightening it, there is alternate action and relaxation in the two opposite muscles 4 and 7, as represented in Fig. 30. So in moving the head back and forth the muscles in front and rear are alternately contracted and relaxed.

There is indeed in every muscle some amount of contraction which is independent of action through the nerves, whether it be reflex, or produced by the will. For this reason the muscles cut off in amputation of a limb retract. So also if the muscles on one side of the face be palsied, those on the other side draw the mouth to that side. The

mouth is held in the middle of the face by the equal action of pairs of muscles. The head, too, is held in equilibrium in the same way.

In what is called wry-neck, this *tonic* contraction, as it is sometimes termed, is greater in the muscles on one side than it is on the other. In some cases a cure can be effected only by dividing the contracted muscles. In strabismus, or squinting, one of the straight muscles of the eyeball contracts too strongly for its opposing muscle, and as in wry-neck, dividing the contracting muscle is often necessary to remedy the difficulty.

88. Compound Muscular Action.—Most motions are not performed by single muscles, but by the joint and agreeing action of several, and sometimes many muscles. And as these muscles may vary to a great extent in their degree of contraction, the motions produced by them are not only compound, but are exceedingly varied. In Fig. 32 you see a pair of muscles, one of which is marked *h*, which extend from the large protuberances behind the ears to the top of the breast-bone.

When they contract *equally*, the head is bent straight forward in the middle line between the muscles, and a line drawn from the middle of the forehead down to the breast-bone would strike exactly at the point where these two muscles unite. But if one muscle contracts more strongly than the other, the head as its bows forward turns toward the side on which is the strongest contraction. And as the degrees of contraction in these two muscles may be varied, so there may be a variation in the degree of inclination of the head to one side or the other, as it is bent forward.

If then a variety in the direction of motion may be produced by variation in the degrees of action in two muscles, one can readily see that an almost infinite variety of motion must result from this variation, where many muscles are called into action.

89. Muscles of the Tongue.—There is no part of the body which exemplifies in so palpable a manner the compound and diversified character of muscular motion as

the tongue. It is mostly a bundle of muscular fibres, apparently mingled together in confusion, but really arranged in perfect order, so that the tongue can be moved with great definiteness in all directions, forward, backward, upward, downward, to either side, and in all intermediate directions.

But all this wonderful variety of movement is produced in obedience to the definite action of nerves, whose fibres are mingled with the muscular fibres of the tongue. And in order to produce each motion there is an agreement of action not only between many of these fibres, but also between multitudes of them.

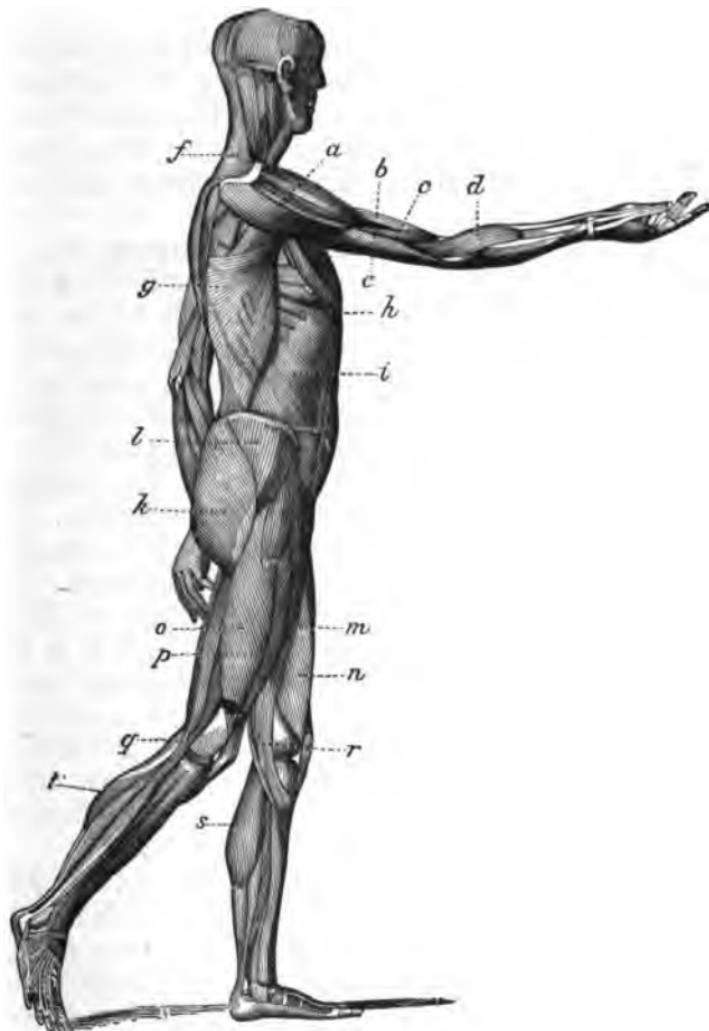
90. View of the Muscles.—The muscles are of various shapes and sizes, according to the motions which they are designed to produce, and the circumstances in which they are placed. They are round, long, short, flat, fan-shaped, circular, serrated, &c. At *a* (Fig. 41) is the very large muscle that makes the fleshy prominence at the upper part of the arm, and the office of which is to raise the arm, carrying it out from the body; its fibres are not all arranged alike, but lie in different directions. The result is, that while the arm is raised by the muscle as a whole, it may be carried at the same time forward or backward by the varying action of these different fibres.

There are many of the muscles of the body which are thus made to produce various results by variation of the action of different parts of the same muscle. And the regulation of this variation by the nerves is one of the most wonderful and mysterious things which we find in our study of the nervous system.

For each fibre, in the cases referred to, is told, as we may express it, just how much it must do in order to produce the requisite general motion of the muscle. It is manifestly much more wonderful thus to produce various but accurately graduated contraction in different parts of the muscle, than to produce a uniform contraction in all its fibres.

At *b* is the biceps muscle, which bends the forearm upon the arm, and at *c* is another muscle that assists the biceps. At *e* is the large muscle in the back of the arm, which acts

FIG. 41.



MUSCLES OF THE BODY.

in opposition to the biceps, and straightens the forearm upon the arm. At *d* is a muscle which rolls the radius outwards, and thus turns the palm of the hand upward as seen in the Figure.

At *g* is a very large broad muscle coming from the whole length of the back. At the axilla or arm-pit, its fibres are collected, twisted, and folded upon each other, and it is fastened by a stout tendon to the upper and back part of the bone of the arm. Its office is to pull the arm backwards and downwards.

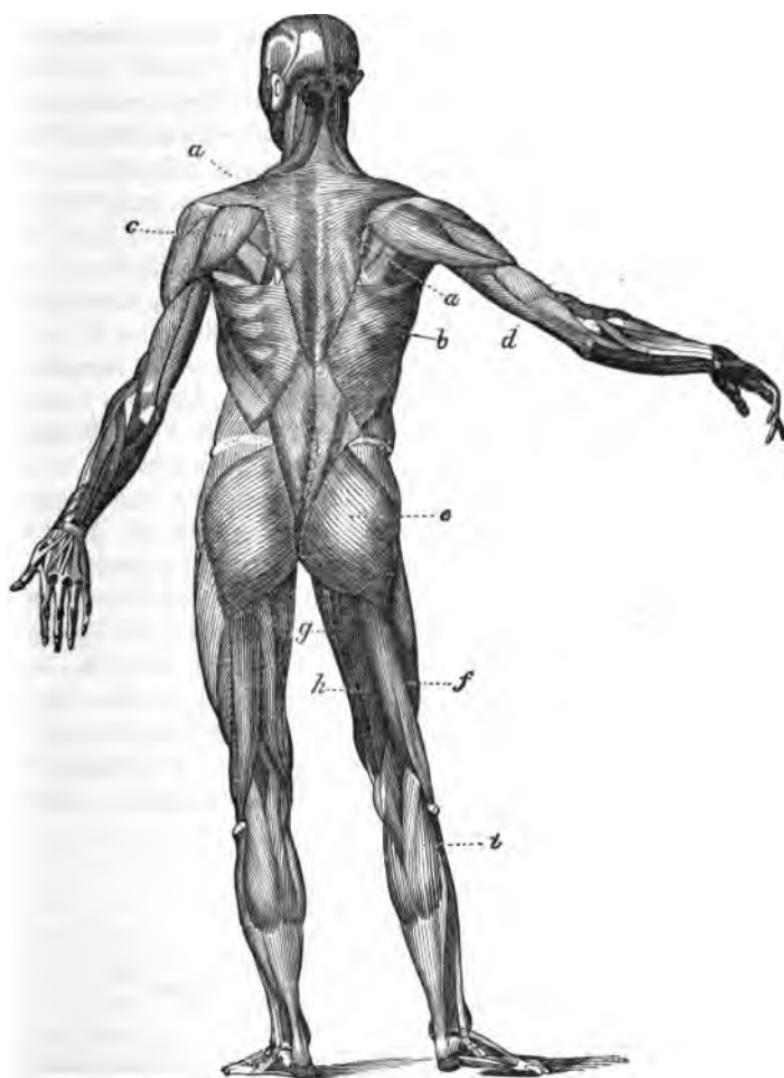
At *h* is a serrated muscle which, rising from the ribs, goes to the shoulder-blade, and serves to draw the shoulder-blade forwards. At *i* is one of the broad muscles of the abdomen. At *l* and *k* are two large muscles that move the thigh. At *o* and *p*, as seen on the right thigh, and at *n*, as seen on the left, are three large muscles, which are fastened to the kneepan, and serve to throw the leg forward.

At *q* is the tendon that forms the outer hamstring, and at *r* are the two tendons which form the inner one. The muscles to which these tendons belong, serve to bend the leg upon the thigh, drawing it upward and backward. At *s* is the muscle which makes the bulk of the calf of the leg. It moves the heel upward and backward, and it is seen in *t* in the right leg of the Figure. Its strong tendon which is attached to the top of the heel-bone is called, on account of its strength, the tendon of Achilles. This muscle is in Fig. 28 the power *P* which raises the weight of the body, *W*, on the fulcrum, *F*, as the heel is raised from the ground in walking.

In Fig. 42 you have a rear view of the muscles. At *a* is a very broad muscle, which, rising from the back, is attached to different parts of the shoulder-blade. You can see that this irregularly-shaped muscle will move the shoulder-blade variously, according to the various action of the different fibres of the muscle, which run in so different directions.

At *c*, you see the rear part of the muscle that raises the arm. At *b* is the extensive muscle that you saw in Fig. 41 at *g*, which draws the arm backward. At *e* is a large muscle

FIG. 42.



REAR VIEW OF THE MUSCLES.

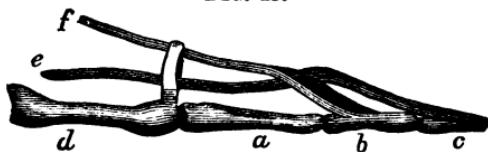
that draws the thigh backward. At *g*, *h*, and *f* are the muscles whose tendons form the two hamstrings. At *i* is the muscle that forms the calf of the leg, and raises the heel.

91. The Bones are not all that the Muscles move.—Thus far the bones have been especially spoken of as being moved by the muscles. But other parts are moved by them also. In the case of the voice, the little muscles move cartilages to which the vocal ligaments are attached. The tongue and the palate are moved by muscles. Muscles move the skin. The mouth, the eyelids, the eyebrows, &c., are moved by them. In many animals the skin is moved extensively by muscles, as, for example, when the horse shakes his skin to get rid of the biting flies.

92. Symmetry of Arrangement.—The muscles moving the fingers are placed mostly in the forearm, while their slender tendons pass over the surface of the bones in the wrist. The flowing outline of the arm is thus secured, and the hand is made a light, and at the same time a strong apparatus. Substantially the same can be said of the arrangement of the muscles and tendons in the leg and foot.

There is a contrivance in a muscle that bends the toes which will be noticed here. Its four tendons pass to the last bones in the toes, and in doing so they go through the tendons of the muscle that bends the second joints. For this purpose, the latter divide near the ends where they join the bones. In the fingers, also, a similar arrangement is made for the tendons of the second and third joints. This

FIG. 43.



is represented in Fig. 43, in which *e* is the tendon which goes to the last bone *c* through the division in *f*, which goes to the second bone *b*. It is manifest that this is the best way of packing the tendons, as we may express it. Any

other conceivable arrangement would add to the bulk of the finger. As they are represented in the figure they are raised up, instead of being closely packed down upon the bone, as they are in reality.

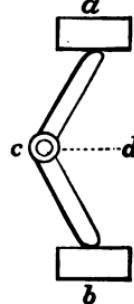
93. Modes of Action of the Muscles.—Your attention is called to one mode of action, in which a large number of the muscles are called into play, on account of its analogy to an expedient often used in mechanics. This, represented by Fig. 44, is called the *toggle-joint*.

Let *c*, *a*, and *c*, *b*, represent two bars connected together, like a carpenter's folding rule, by a hinge or joint at *c*. Suppose the two ends, *a* and *b*, to be fitted into the two blocks represented in the Figure. If now the block at *b* is fixed, and the block at *a* is movable, and force be applied to the joint *c* carrying it towards *d*, the block at *a* will be pressed upward with considerable force. If, on the other hand, the block at *b* is movable, and that at *a* is fixed, the block at *b* will be pressed downward. We see this latter form of the contrivance applied in printing-presses.

In the human body this toggle-joint is used in both ways. When one stoops to take a heavy weight upon his back or shoulder, he puts both the knee and the hip-joints in the condition of the toggle-joint when it is bent; and then as he straightens up, the weight is raised by an action of the joints precisely similar to that of the toggle-joint in machinery. In the case of the knee, the straightening of the joint is done by the muscles on the front part of the thigh, that draw up the kneepan with the tendon attached to it.

This is using the principle of the toggle-joint in pressing upward. It is also sometimes used in pressing downward. In crushing any thing with the heel, we give great force to the blow on the principle of the toggle-joint, by flexing the knee and straightening the limb as we bring down the heel upon the thing to be crushed. In pushing any thing before us,

FIG. 44.



TOGGLE-JOINT.

we bend the elbow as preparatory to the act, and then thrust the arm out straight, thus exemplifying the toggle-joint.

The horse gives great force to his kick in a similar manner. The great power exerted by beasts of draught and burden is to be referred mainly to the principle of the toggle-joint. When a horse is to draw a heavy load, he bends all his limbs, especially the hinder ones, and then as he straightens them, he starts the load. In this case the ground is the fixed block of the mechanism, the body of the horse to which the load is attached is the movable one, and his limbs are so many toggle-joints. By this application of the principle we see draught-horses move very heavy loads.

94. The Hand.—The hand is the most wonderful of all parts of the body, in regard to variety and complication of movement. There are over fifty muscles, which are engaged in the various motions of the upper extremity, all of which, of course, have more or less reference to the hand. Indeed the hand is the part of the upper extremity to which all its other parts are tributary, and therefore we may properly consider all these muscles as in a great measure belonging to the hand.

If now you call to mind the fact, that each one of these muscles can vary the *amount* of its contraction in all degrees, from the most powerful action down to the slightest movement, you can readily see that fifty muscles with this power of variation can produce an *almost endless* number of combinations of motion. The variety would be exceedingly great, even if every muscle, whenever it acted, had always the same amount of contraction. But the power of varying the amount of contraction multiplies the variety to an inconceivable extent.

95. The Muscular Sense.—The question arises, how in all the diversified action of the muscles their nice adjustment is effected. How do the muscles *know*, as we may express it, just how much to do in each movement? When, for example, you reach your hand up to touch some object, how does each muscle know just what degree of contraction is necessary to make the hand go with precision to

the particular point arrived at? And so when one is playing on an instrument with the fingers, as the piano, varying their pressure continually in accordance with the desired loudness of the sound, how does each muscle know just what amount of contraction is required of it in each movement? Though the senses of vision and touch afford some assistance in the guidance of muscular action in such cases, something else is manifestly necessary.

Sir Charles Bell, therefore, supposes that there is what he calls a *muscular sense*, which acts as a guide to the muscles, in connection with the senses of sight and touch. In some cases it is the sole guide. On this subject, Sir Charles says, "When a blind man, or a man with his eyes shut, stands upright, neither leaning upon nor touching aught; by what means is it that he maintains the erect position? The symmetry of his body is not the cause; the statue of the finest proportion must be soldered to its pedestal, or the wind will cast it down.

"How is it, then, that a man sustains the perpendicular posture, or inclines in due degree towards the winds that blow upon him? It is obvious that he has a sense by which he knows the inclination of his body, and that he has a ready aptitude to adjust it, and to correct any deviation from the perpendicular. What sense then is this? He touches nothing, and sees nothing; there is no organ of sense hitherto observed which can serve him, or in any degree aid him. Is it not that sense which is exhibited so early in the infant, in the fear of falling? Is it not the full development of that property which was early shown in the struggle of the infant while it yet lay in the nurse's arms?

"It can be only by the adjustment of muscles that the limbs are stiffened, the body firmly balanced, and kept erect. There is no source of knowledge, but a sense of the degree of exertion in his muscular frame, by which a man can know the position of his body and limbs, while he has no point of vision to direct his efforts, or the contact of any external body.

In truth, we stand by so fine an exercise of this power, and the muscles are, from habit, directed with so much precision, and with an effort so slight, that we do not know how we stand. But if we attempt to walk on a narrow ledge, or stand in a situation where we are in danger of falling, or rest on one foot, we become then subject to apprehension; the actions of the muscles are, as it were, magnified and demonstrative of the degree in which they are excited."

CHAPTER VI.

LANGUAGE OF THE MUSCLES.

96. All Thought Expressed by Muscular Contractility.—As the nerves of sensation are the inlets of all knowledge to the mind, the nerves of motion are the outlets by which all knowledge is communicated. Thought and feeling are expressed only by muscular motion.

It is chiefly by the voice that thought and feeling are communicated. And every variation of note, or of articulation, is caused by the action of muscles. When the muscles of the hand, by writing, communicate to others thought and feeling, they merely translate the language of the muscles of the vocal organs into conventional signs. Leaving the language of these vocal muscles for another chapter, in this we will notice the language of the other muscles of the body and especially of those of the face.

97. Muscles of Expression in the Face.—The particular muscles of expression in the face, are represented in Fig. 45. There is a thin flat muscle covering the whole top of the head, represented at 1, 2, and 3; 3 being its thin tendinous part. It is fastened to the large bones behind, and in front its fibres end in the skin of the forehead and the eyebrows, and in the circular muscle of the eyelids, 4. When it contracts, therefore, it raises the

skin of the forehead and the eyebrows; and if it contract strongly, it wrinkles the forehead. The circular muscle of the eyelids, 4, when it contracts closes the eye. This and the large frontal muscle just described, must have much to do with the expression of the countenance.

FIG. 45.



MUSCLES OF THE FACE.

A very important though small muscle, not seen in the figure, may be seen at *a*, in Fig. 32. It is attached to the bone at the side of the top of the nose, and is inserted into the skin of the eyebrow. It is called the *corrugator supercili*, or wrinkler of the eyebrow. From the agency which this muscle has in the expression of certain passions and emotions, comes the word in so common use, *supercilious*. Though a little muscle, it is truly a *supercilious* one.

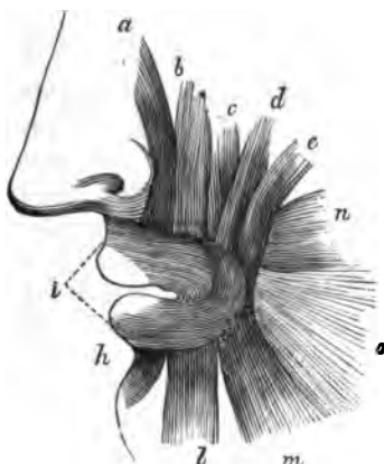
At 7 is the circular muscle of the mouth, *orbicularis oris*. When this contracts it closes the lips, and if it act strongly it pushes them out. This is the muscle with which, in part, pouting is done. At 8 is a muscle which is fastened above to the bone of the nose, and runs down, its fibres ending in

the wing of the nose, and in the upper lip. When it contracts, therefore, it moves the wing of the nose outward, and draws up the lip. You see this muscle in action in some emotions, the nostrils appearing spread out. At 9 is a muscle which raises the lip, and at 10 and 11 are two muscles, that raise the corner of the mouth, carrying it a little to one side. At 13 is the muscle which acts in opposition to the two last. It pulls the corner of the mouth down. At 12 is the muscle which pulls down the lower lip. At 18 is the muscle in the side of the mouth, which draws the corner of the mouth backward, and also serves to press the cheek inward, and thus prevent the food from getting outside of the teeth when we are chewing it. This muscle also, by its compressing power, forces out the air from the mouth when the cheeks are distended, as in blowing a horn or a trumpet. Hence it is called *buccinator* from *buccinare*, to blow a trumpet. At 15 is a large muscle which closes the lower jaw against the upper, and although its chief use is to masticate the food, it has some agency in the expression of the countenance, in fixing the teeth firmly together, as in the expression of rage. There are three muscles which move the ear: 19, moving it upward; 17, forward; and 21, backward. These have but little power in man, but in some animals they move the ear considerably, and are prominent agents of expression.

98. Muscles about the Mouth.—In Fig. 46 the muscles about the mouth, which have so much to do with the expression of the countenance, are very distinctly shown. At *a* is the muscle which draws up the wing of the nose and the lip; *b* raises the lip; *c* raises the corner of the mouth; *d* and *e* raise the corner of the mouth, and at the same time carry it outward; *n* draws it outward; *m* draws it downward and outward, in which action it is assisted by a broad thin muscle, *o*, which, situated just under the skin, comes up from the neck; *l* draws the lower lip downward; and *i* is the circular muscle which closes the lips, and thrusts them out in pouting. At *h* is a short muscle which is fastened to the sockets of the teeth, and has its fibres ending

in the skin of the chin. It therefore draws the chin up when it contracts. It has so much agency in the expression of scorn and contempt that it has been called the *superbus*. It is by the action of this muscle, together with the circular muscle *i*, that the expression termed pouting is produced.

FIG. 46.



MUSCLES ABOUT THE MOUTH.

Most of the muscles which have been described are in *pairs*; and in every pair both muscles contract always exactly alike, unless affected by disease. We laugh and frown and weep on both sides alike. All of these muscles of expression in the face are governed in their action by the branches of one nerve, the respiratory nerve of the face. When this nerve, therefore, is paralyzed on one side, and not on the other, as is no uncommon occurrence, these muscles on the paralyzed side are motionless, and the individual can laugh and frown and weep on only one side of the face.

No one muscle is devoted to the expression of one emotion or passion; expression is commonly the result of the combined action of many muscles. By virtue of this combination, the same muscle often takes a part in the expression of various emotions.

99. Action of Particular Muscles in Expressing Emotions.—When the frontal muscle (1, 2, 3, Fig. 45) contracts it raises the eyebrows. This motion expresses either doubt or surprise, and the observer determines which it is, by the expression of other parts of the countenance accompanying it, or in other words, by the action of other muscles in the face. When this muscle contracts very strongly, it draws up the eyebrows so much, as to push up the skin of the forehead, and wrinkle it. This, as you will soon see, is one of the many motions of the face which make up the expression of great bodily fear. In joy this muscle acts moderately; raising the eyebrow, therefore, but a little. This muscle often acts in connection with the *corrugator supercilii*, the wrinkler of the eyebrow. The muscle which draws the corner of the mouth down is in action while the *superbus* (*h*, Fig. 46,) is drawing up the chin which pushes up the lip before it. At the same time the muscle which draws up the wing of the nose and the lip (*a*, Fig. 46,) contracts to some extent, producing an arching of the mouth and a peculiar shape of the wings of the nose. The upper lip is arched by the action of this muscle in such a way as to fit the arching upward of the lower lip, produced by the *superbus* and the muscle which draws down the corner of the mouth.

In the expression just described, and illustrated by the figure, it can be seen that the muscle which draws down the corner of the mouth has a considerable agency. Now, this muscle is the chief agent in the expression of sorrow, as you saw in the first part of this chapter. The difference in the two cases lies in the *combination* of action of the muscles. Thus, in sorrow the muscle which draws down the corner of the mouth, does not have the *superbus* to act with it, as in the case of the passion. So also, in some forms of grief, the *corrugator supercilii* acts quite strongly, where the grief is represented as caused by bodily pain.

In quiet sorrow this muscle is not in action, but there is a general languor relaxing the muscles of the face, while the corners of the mouth are slightly depressed. It is a state of the muscles directly opposite to that which exists

when there is a calm quiet pleasure. Then most of the muscles are in a state of gentle action, and the corners of the mouth are a little raised, giving the radiance of a light smile to the whole countenance. The frontal muscle slightly raising the eyebrows, adds to the effect.

100. Movements of the Eye in Expression.

—The muscles of the eye, that is, those which move the eyeball, have some agency in certain expressions of the countenance. Thus, the fixing of the eye upon an admired object makes a part of the expression of admiration. In the expression of devotion the eye turns instinctively upward. There are certain involuntary motions of the eyeball, which have much to do with expression in certain states of the body, and in certain emotions. These motions are performed by the oblique muscles. When the straight muscles which ordinarily control the motions of the eye lose their power from a state of general insensibility, the eye is given over to the action of these oblique muscles, which are involuntary, and therefore is rolled about in its socket, being turned upward all the time, so that only the white of the eye is seen. This occurs in sleep, in fainting, in the stupor of disease, and in the approach of death.

The loss of power in the voluntary muscles of the eyeball and eyelid is often seen ludicrously exhibited in the intoxicated man. He squints and sees double from deficiency of action in the straight muscles of the eyeball. The oblique involuntary muscles of course roll the eye in proportion to the deficiency of these straight muscles. The voluntary muscle too, which holds up the upper lid, fails to do its duty, and the lid is constantly disposed to fall over the eye. The frontal muscle is therefore called upon to aid it. Hence, in the effort of the drunkard to keep his eyes open, you see him raise the eyebrows, the eyelids of course being dragged up after them slightly.

101. Combination of Muscular Action.—But we do not get a full view of the combinations of muscular action in expression, if we confine our observations to the countenance. The muscles of other parts of the body, and

sometimes of the whole frame, are brought into action in connection with the muscles of the face, in expressing thought and feeling. The attitudes and motions of other parts of the body correspond with the attitudes and motions of the countenance, so as to produce a harmonious effect. The hand is more used than any other part in aid of the countenance in expression; but the whole body is often brought more or less into action. The character of a passion can sometimes be inferred merely from the attitude or from the mode of walking, as you see one at a distance.

102. Action of the Respiratory Muscles.—But it is the muscles of the respiratory organs which sympathize most with the muscles of the face in expression. This sympathy is the result of a nervous connection, and the nerve of expression in the face is therefore sometimes called the respiratory nerve of the face. In laughing the individual draws in a full breath, and then lets it out in short interrupted jets, the muscles of the throat, neck and chest, especially the diaphragm, being convulsively agitated. And if the laughter be strong and continued, he holds his sides, which become really sore, from the violent action of the respiratory muscles in this expression of his emotions. In weeping too, these same muscles are affected. The diaphragm acts spasmodically, the breathing is cut short by sobbing, the inspiration is quick, and the expiration is slow, and often with a melancholy note. But it is not alone in these marked cases that the respiratory muscles are seen to act, their action is plainly noticeable in many of the slighter expressions of feeling.

103. The Habitual Expression of the Countenance after Death.—The habitual expression of the countenance, depending as it does upon the habitual condition of the muscles, is seen after death. In the state of relaxation which occurs immediately at death the face is very expressive, because its muscles, together with those of the whole body, are so entirely relaxed. But very soon they begin to contract, and they assume that degree of contrac-

tion to which they were habituated during life, and therefore give to the countenance its habitual expression.

MUSCLES.	CHARACTER.	{ FIBROUS. CONTRACTILE.
	FUNCTION.	{ MOTION. { Voluntary. Involuntary.
	ATTACHMENT.	{ BY TENDONS TO THE BONES. (NOT SO ATTACHED.
	ARRANGEMENT.	{ DEEP-SEATED. SUPERFICIAL.

CHAPTER VII.

DIGESTION.

104. Summary of the Process of Digestion.

—Under the term digestion are included all those processes which are necessary to effect the separation from the food of its nutritious portion, and the introduction of it into the circulation. A summary of these processes may be thus given. The food is broken up and ground in the mouth, and it is at the same time mixed with the saliva. It is then taken into the stomach, where it is kept in constant motion under the solvent action of a fluid of a peculiar character. When it is brought into the right condition, it is passed from the stomach into the intestines. Here it is acted upon by two fluids—the bile, the secretion of the liver, and the secretion of another gland, the pancreas or sweet-bread. These secretions have some agency in separating from the mass its nutritious portion, and this is absorbed or taken up, in the form of a milky fluid, by little vessels lying on the surface of the inner membrane of the intes-

tines. These vessels unite to form a large tube, through which the milky fluid is poured into the circulation, to replenish the blood.

105. Teeth Various, according to Different Kinds of Food.—Mastication is an important part of the process of digestion. The teeth, which perform this act, are very hard bodies. The body of a tooth is composed of two substances. The inner part is called the ivory, and the outer, which is exceedingly hard, is called the enamel. The teeth are of different shapes for different modes of action. There are long and pointed teeth, for tearing; others for cutting, which have a sharp edge; and others for grinding, which have for this purpose a broad and irregular surface.

The teeth are differently shaped in different animals, according to the kinds of food which they eat. Thus, the herbivorous, or vegetable-eating animals, have grinding teeth to bruise their food; while the carnivorous, or flesh-eating animals, have sharp-edged teeth, and long-pointed teeth, by which their food is torn and cut in pieces. And it is to be observed, that the movement of the jaws always corresponds to the character of the teeth.

In the carnivorous animals, the motion of the lower jaw upon the upper is a mere up-and-down, or hinge-like motion. As they have no grinding teeth, there is no need of any lateral motion. But in the animals that have grinding teeth, there is a lateral motion, to enable them to grind. You see this difference very plainly, if you observe the dog and the horse while they are eating. In Fig. 47 you see represented the teeth of a carnivorous animal. The front teeth are long and pointed, for rending, while the back teeth have a sharp edge for cutting.

In Fig. 48 you see represented the broad and irregular grinding surfaces of the teeth of herbivorous animals. In animals that live on insects, the teeth present conical points, which press into corresponding depressions in the opposite jaw, as represented in Fig. 49. In those that live on soft fruits, the teeth are rounded, as in Fig. 50. These

are quite in contrast with the tearing teeth of the carnivorous, and the grinding teeth of the herbivorous animals.

FIG. 47.



TEETH OF CARNIVOROUS ANIMAL.

There is an arrangement of the enamel and the ivory in the teeth of the herbivora which ought not to pass unnoticed. Instead of having the enamel cover the ivory, as in the teeth of the *carnivora*, the two substances are arranged in

FIG. 49.



TEETH OF INSECTIVOROUS ANIMAL.

upright layers, as seen in Fig. 48. The object of this is plain. The ivory wears away more readily than the harder enamel, and, therefore, the surfaces of the teeth always present projecting hard ridges, fitting them for grinding thoroughly. A miller would say, that these are stones that never need picking.

106. Man an Omnivorous Animal.—So perfect is the correspondence of the teeth with the kind of food on which the animal lives, that the skillful naturalist can infer very correctly, from the examination of the teeth

FIG. 48.



TEETH OF HERBIVOROUS ANIMAL.

FIG. 50.



TEETH OF FRUGIVOROUS ANIMAL.

alone, the character of the food on which an animal lives, and even the general arrangement of its structure.

As man has the three kinds of teeth which I have noticed, he is said to be *omnivorous*, or an eater of all kinds of food. In him, the front teeth are the cutting ones; what are called the stomach and eye-teeth are the tearing ones; and the large back teeth are shaped for grinding. It will be observed that the tearing teeth, as they have not very sharp points and are no longer than the other teeth, have but little power when compared with the long and sharp tearing teeth of a carnivorous animal, as seen in Fig. 47. As man can use instruments to cut his food in pieces, he does not need so much power in his teeth as carnivorous animals have. Allowance should be made for this in estimating the amount of carnivorous adaptation in man.

107. Substitutes for Teeth.—There are a few of the Mammalia that have no teeth. This is the case with the common whale. In his case, instead of teeth, there hang down from the upper jaw, as represented in Fig. 51,

FIG. 52.



WHALEBONE.

FIG. 51.



SKULL OF WHALE.

plates of a fibrous substance, called whalebone, which have their fibres separated at their free extremities, so as to make a sort of sieve. This is intended to catch the small animals, which the whale devours in great numbers.

To obtain these it swims with its mouth opened and thus fills it with water. The water is strained through the

fibrous whalebone, and the small animals retained. Birds, too, have no teeth. Their place is supplied in part by a contrivance in the stomach itself, for the breaking up of the food. This will be described in another part of this chapter.

108. Salivary Glands.—While the food is cut and ground by the teeth, it is at the same time thoroughly moistened by the saliva, which is poured forth from certain glands in the neighborhood. There are three pairs of these glands. Fig. 53 shows the glands on one side. The parotid

FIG. 53.



SALIVARY GLANDS.

gland, 1, is the largest. This is situated in front of the lower part of the ear. It is the seat of the swelling in the disease called mumps. Its duct, 2, passes over one large muscle and between the fibres of another, and pours its contents into the mouth opposite the second small grinder of the upper jaw. If you press on this part of the cheek, you can feel in the mouth an increased flow of the saliva.

The submaxillary gland, 3, is situated inside the lower jaw at its lower part; and its duct, 4, opens into the mouth at the side of the frenum of the tongue. The sublingual gland, 5, lies under the tongue, and discharges its secretion by ducts at the side of that organ.

109. Action of the Salivary Glands.—These glands are especially active when we are eating ; and it is commonly estimated that, during an ordinary meal, about eight ounces of saliva are poured into the mouth. This large amount is wanted to moisten the food thoroughly before it is swallowed ; and it also has some chemical influence in preparing the food for the action of the gastric juice in the stomach. More saliva than usual is needed, also, when we are speaking, in order to keep the parts properly lubricated, for the passage of the air in and out during speaking dries up the saliva by evaporation. And, accordingly, the motion of the parts at such times stimulates a larger flow, just as pressure on the cheek will do it, as before remarked. This result is favored by the course of the duct of the parotid gland, which, as you have seen, passes over one large muscle, and then through the body of another.

Chewing excites an increased flow of the saliva ; and the tobacco chewer does a real injury to the salivary glands, by keeping them constantly in excessive operation, to say nothing of the ruinous effects of this drug on the system at large.

110. Flow of Saliva affected by Sympathy.—It is supposed that, besides the mere mechanical stimulus of the motion of the parts, the stimulus of sympathy is also concerned in exciting these glands to increased action. The glands are supposed to be affected in this way by the stimulation of the food on the surface of the mouth, about the orifices of their ducts. That sympathy does have an influence on their secretion is evident from the very familiar fact, that the thought of food will often, as it is expressed, cause the mouth to water.

111. Difference in the Character of the Saliva.—The fact that these glands do not all secrete the same kind of fluid, has led to an interesting discovery in relation to them. The submaxillary glands secrete a viscid fluid, while that which is poured forth by the parotid and sublingual glands is perfectly limpid. Now it has been found, by various observations and experiments on animals,

that while the teeth are cutting and grinding the food, and the parotid and sublingual glands are pouring out the saliva to moisten it, no secretion comes from the submaxillary glands.

But these glands pour out their viscid fluid the moment that the tongue thrusts the food back towards the throat, in the beginning of the act of swallowing. The special object of this viscid fluid is then to cover the food, so that it may, to use a common expression, slip down easily into the stomach ; and it has nothing to do with the moistening of the food, this being the particular office of the other two pairs of glands.

112. Swallowing.—When the food has been ground by the teeth, and moistened by the saliva, it is carried by the act of swallowing into the stomach. This act, simple as it may appear to you, is a very complicated one, and is performed by the conjoined and agreeing action of many different muscles. The food is first thrust back over the surface of the tongue into the large cavity in the back of the throat, called the pharynx. Into the pharynx two tubes open—the *œsophagus* or gullet, which is the passage into the stomach, and the trachea* or windpipe, the passage to the lungs.

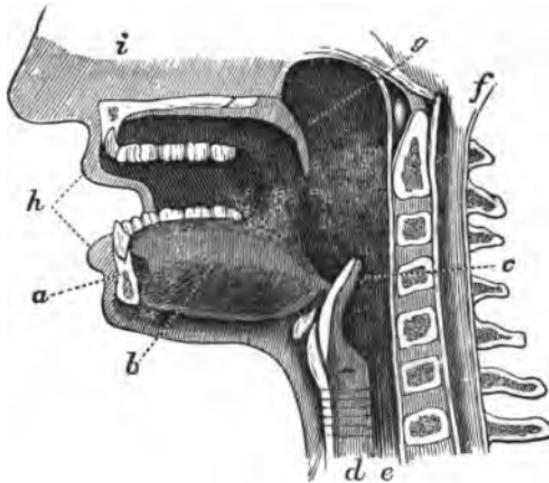
As the *œsophagus* lies behind the trachea, the food, in passing to it, must go directly over the opening into the trachea. To prevent the food from entering the trachea, therefore, there is a little tongue-shaped body, called the epiglottis, extending back from the root of the tongue, and acting as a lid to the glottis, the opening into the trachea.

When we are swallowing, this lid is shut down ; but it is always raised up when we are breathing or speaking. When we swallow, not only does the lid shut down, but the larynx rises to meet the lid, as you may readily perceive, if you place your fingers upon what is called Adam's apple while

* This term is sometimes used, as here, to mean the whole of the tube conducting to the lungs, including the larynx, which is at the top of this tube, and sometimes it is restricted to that part of the tube which is below the larynx.

you are swallowing. In Fig. 54, you have a *side* view of the parts engaged in swallowing, as if the head were divided into two halves by a vertical section. At *i*, is the cavity of the nostril; at *h*, are the lips; *a* is the divided bone of the chin; *b* is the tongue, between which and the spinal column, is *f*, the large cavity of the pharynx. In front of this cavity hangs the palate, *g*, as a door or valve, to direct the air coming from the trachea, *d*, either through the mouth or through

FIG. 54.



VERTICAL SECTION OF THE THROAT.

the nostrils, according to its position. The oesophagus, *e*, is behind the trachea, and the epiglottis, *c*, shuts down when we swallow, to let the food pass over it into the oesophagus. In Fig. 55, you have a view of the same parts from the rear. At 1, is a section of the bones at the base of the skull; 3, 3, are the cavities of the nostrils; 2, 2, the walls of the pharynx spread apart; 5, the pendulous palate; 6, 6, the arch of the palate; 8, the root of the tongue; 9, the epiglottis, and 10, the glottis, or opening into the larynx; 13, the oesophagus; 14, the trachea. The pharynx, you see, is a funnel-shaped cavity, tapering down to the oesophagus, the opening of which is considerably below the opening of the trachea.

113. Action of the Oesophagus.—When the food enters the oesophagus, it is carried through that tube into the stomach by the action of muscular fibres. These fibres are represented in Fig. 56. The circular fibres are seen at *a* and *b*. These are removed at *c*, so as to show the longitudinal fibres. It is by the consent of action between these different sets of fibres that the food is propelled through the oesophagus.

As the food descends, a dilatation of the circular fibres must everywhere take place where the food is, and a contraction of them immediately behind it—the dilatation making the way for it, and the contraction forcing it along. And in animals that chew the cud, these actions force the food from the stomach into the mouth.

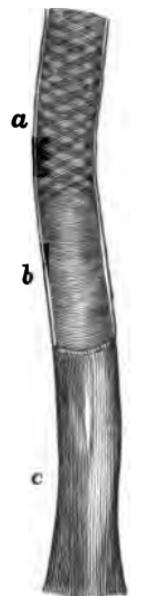
114. The Gastric Juice.—The food being introduced into the stomach, is here subjected to the action of the gastric juice. This is a peculiar fluid, somewhat acid in its character, which is secreted by very minute follicles, or bag-like cavities, situated in the substance of the mucous membrane. Ordinarily there is none of this fluid in the stomach when no food is there. Dr. Beaumont made some very interesting observations on this, as well as many other points, in the remarkable case which fell under his care. His patient, Alexis St. Martin, had received a wound in his left side by the bursting of a gun. The wound, which

FIG. 55.



VIEW OF THE THROAT FROM BEHIND.

FIG. 56.



CESOPHAGUS LAID OPEN.

opened into the stomach, never entirely closed, but an orifice remained, through which Dr. Beaumont could look into, and observe what was going on in the stomach.

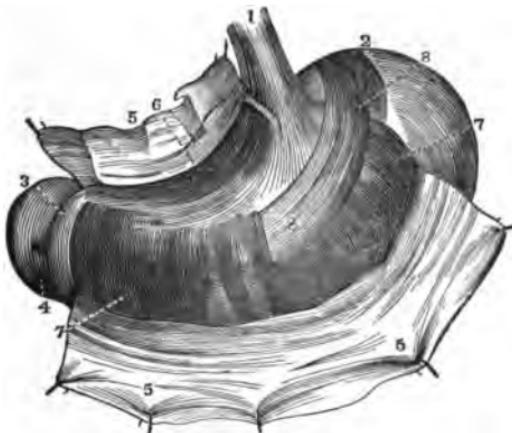
He describes the mucous membrane, in its healthy state, as having a velvet-like appearance, with a pale pink color, and as being covered with a very thin, transparent, viscid mucus. On introducing some food, or irritating the mucous membrane mechanically, he saw, by the aid of a magnifying glass, "innumerable lucid points" projecting on the surface, and from these exuded a pure, limpid, colorless fluid. These points were the follicles which secrete the gastric juice, rendered turgescent by being stimulated to action.

115. Quantity of Gastric Juice.—The amount of gastric juice secreted is generally about in proportion to the amount of food which the necessities of the system require. When the quantity of food taken is very much more than is required, there can not be a sufficient amount of gastric juice secreted to digest all of it; and some must therefore remain undigested, and will prove a source of irritation to the stomach. If the amount of food taken from day to day is not very excessive, but is only a little above the proper quantity, there will be enough gastric juice made to digest it; but the daily overtaxing of the powers of the secreting follicles will, after a while, produce derangement of the stomach, and perhaps permanent disease.

116. Function of the Gastric Juice.—The action of the gastric juice upon the food is of a chemical nature. In order that it may act effectually on all portions of the contents of the stomach, this organ is kept in constant motion by the fibres of its muscular coat. These fibres are so arranged that, as they contract and relax, they keep up a sort of churning of the contents, and thus effect a thorough mixture of them with the gastric juice. In Fig. 57, you see these fibres represented. At 1, is the opening of the œsophagus into the stomach; and at 4, is the part which opens into the intestine. The fibres are in different

layers, running in different directions. The outer peritoneal coat, 5, 5, is dissected off and turned back, showing some of

FIG. 57.



MUSCULAR FIBRES OF THE STOMACH.

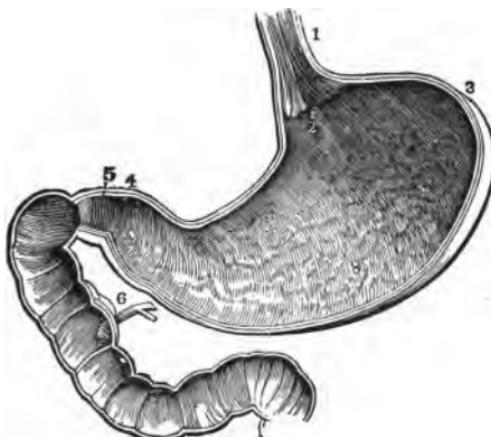
the fibres that run lengthwise of the organ, 6; and some that run crosswise, 7; and others, 8, that run obliquely. You can readily see what effect the contraction of these different fibres will have on the shape of the stomach. The contraction of the longitudinal fibres, 6, brings the large, bulging end of the stomach, 2, and the small end, 3, nearer together. The transverse fibres, when they contract, diminish the capacity of the stomach transversely. And the oblique fibres modify these two motions by their oblique action.

117. Action of the Pylorus.—By the combined chemical and mechanical action of the stomach, its contents are, after a little time—in three or four hours—reduced to a uniform greyish, semi-fluid mass, called *chyme*. While this process has been going on, the communication between the stomach and the intestines has been entirely closed by a valve, called the pylorus. This is represented at 5, in Fig. 58, which presents a view of the inside of the stomach. This valve is made of a fold of both the mucous and the muscular coats of the stomach. It is a very faithful sen-

tinel, as is indicated by its name, which is derived from two Greek words, signifying to guard the gate. It will not ordinarily permit any undigested food to pass it.

While the process of digestion is going on, the motions produced by the muscular fibres cause the contents to move about, and of course they are thrown against the pylorus, as well as any other part of the stomach. But the valve remains closed, until some portion comes against it that is thoroughly changed to chyme, and is therefore fit to pass on into the intestine. It opens to let this pass.

FIG. 58.



INTERIOR OF THE STOMACH AND SMALL INTESTINE.

Toward the conclusion of the digestion of a meal, small quantities pass at first, and after a while, the contents pass quite rapidly through the valve.

Although this sentinel-valve thus performs its duty so faithfully in relation to nutritive substances, it seems to let other substances pass very readily. Solid substances, swallowed by mistake, as buttons, pieces of money, the pits and skins of various fruits, often pass the valve without any trouble. The valve seems to be on duty as a sentinel only during the process of digestion; and, if the attempt to go through with this process prove unavailing, the pylorus,

though it let such hard substances as have been mentioned pass without difficulty, resists the passage of the undigested food, sometimes causing much uneasiness, and even perhaps pain, by so doing. In such a case, either the valve after a time gives over its resistance, or, holding out, the action of the stomach is reversed, and the offending matter is thrown off by vomiting.

118. Bad Habits in Eating.—The process of digestion, as it has been described, is a regular process, requiring a certain average period of time for its completion. If, during the progress of it, fresh food be introduced, its regularity is broken in upon, and the process stops. Then, too, if, immediately after the completion of the process, a new supply of food be taken, harm is done, because the organ has not its needed interval of rest. For these reasons, the practice of eating between meals is a very injurious one.

Eating fast does harm, because,—1st, the food is not sufficiently ground; 2d, it is not mixed thoroughly with the saliva; and, 3d, more food is taken than would be sufficient to satisfy the hunger if the individual ate slowly, and, therefore, more than can be easily digested. Great variety in food stimulates the appetite unduly, and too much is consequently eaten. Moderate exercise, if it be not violent, facilitates digestion. An experiment was once tried upon two dogs, which was thought to prove that exercise hinders digestion.

Two dogs were fed freely, and while one was left to lie still, the other was made to run about violently. Both dogs were killed after an hour or two, and it was found that, while digestion had gone on thoroughly in the dog that was allowed to remain quiet, in the other the food was undigested. This only proved that *violent* exercise, taken immediately after eating, impedes digestion. It has been found, on the other hand, that light exercise promotes the process; and daily experience, among laborers, shows, that even very strong exercise does not interfere with it, if a little interval of rest be allowed, so that the process may be fairly begun.

119. Cause of Hunger.—The sensation of hunger has been attributed to various causes,—as the empty state of the stomach, the presence of the gastric juice irritating the mucous membrane, &c. It cannot arise from emptiness; for, if so, it should occur sooner than it does after eating, and should not be absent in disease, as it often is for a long time, when the stomach is almost entirely empty. It can not arise from irritation by the gastric juice; for it was found by Dr. Beaumont, in his observations of the stomach of Alexis St. Martin, that this fluid is not secreted till after food is introduced into the stomach. The cause of hunger is evidently in the state of the system. It is a state of want.

Nutriment is needed by the formative vessels, the builders and repairers of the system, which make their wants known as distinctly as the bricklayer does, when he calls for more brick and mortar. Through the nerves, an impression is communicated to the stomach, and the sensation of hunger is the result.

That the sensation results from impressions made upon the nerves of the stomach is evident from the fact that it can be temporarily relieved by putting indigestible substances into the stomach. These produce the effect by causing other sensations, which take the place, for the time being, of the sensation of hunger. After, however, the momentary effect is over, the sensation of hunger returns in its full force. The *cause*, then, of the sensation is in the system at large, but its *seat* seems to be in the stomach.

If disease has impoverished the system, so soon as the stomach is in a condition to respond to the call of the formative vessels that set themselves at work to repair the waste, the hunger is often excessive. In order to have the sensation of hunger, not only must there be a want in the system at large, but the stomach must be in a state fitted to receive the notice of this want. And fortunately it is seldom in this state except when in a condition to do its work. If it were otherwise, food would often be introduced when it could not be digested.

120. *Sensations of Hunger Affected by the Mind.*—Mental impressions sometimes incapacitate the brain for receiving the notice of the want of the system. In this case, the mental impression in the brain counteracts the impression conveyed from the stomach, and so neutralizes the sensation of hunger. Thus, grief often destroys the appetite for food.

121. *Thirst.*—Nearly the same remarks can be made in relation to thirst, that have been made in regard to hunger. This sensation seems to have its seat in the fauces or throat. Its cause is evidently not there; for the mouth and throat may be very dry, and yet there may be little or no thirst; while, on the other hand, there may be much thirst, although the mouth and throat are moist. The cause of the sensation is, like the cause of hunger, in the system at large; and, therefore, no local cause, producing a dryness of the throat, can cause thirst independent of a general condition.

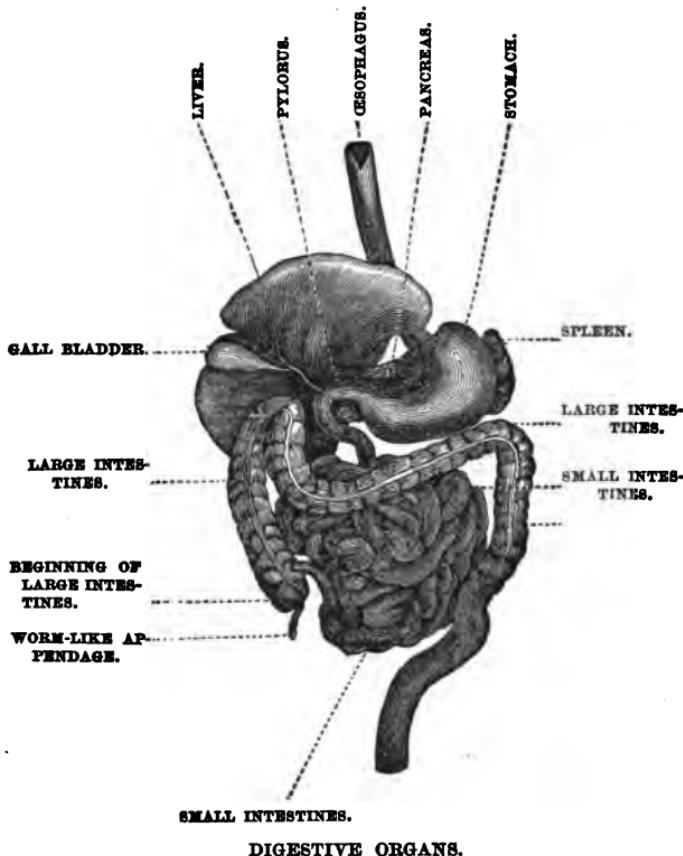
122. *Arrangement of the Organs of Digestion.*—Fig. 59 exhibits the organs of digestion as they present themselves in a front view, except that they are somewhat separated from each other, instead of being as closely packed, as they are in the abdomen. The large end of the stomach lies to the left side,* and at this end is the spleen. The pancreas is behind the right end of the stomach. Above the stomach, and mostly to the right side, is the largest organ in the abdomen, the liver. In the Figure, it is represented as turned upward. The stomach is directly connected with the small intestines at the pylorus. At the end of this long and winding tract begin the large intestines. The duct of the gall bladder, and that of the pancreas, open into the small intestine at its beginning.

The office of the spleen has not yet been ascertained. Neither has that of the worm-like appendage at the beginning of the large intestines. The omentum, or caul, which hangs like a curtain from the front part of the stomach down in front of the intestines, is not represented in the Figure.

* As this is a *front* view, the right side of the Figure is the left side of the body.

123. The Mesentery.—There is one arrangement in the abdomen which must not pass unnoticed. If the intes-

FIG. 59.



tines were left to lie loose in this cavity, they would constantly be subject to displacement and injury. They are therefore fastened to the backbone by an arrangement which secures them from any such accident, and at the same time allows of a sufficiently free motion of different parts of this tube. It is this. The intestinal tube makes the margin of a broad sheet of membrane, the other edge of which is gathered up and fastened to the spinal column.

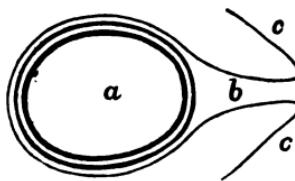
The device is like a ruffle with a puffed edging. The membranous sheet is called the mesentery. As the intestinal tube, the puffed edging, is much longer than the ruffle itself, the mesentery, it is gathered on to the ruffle, as a seamstress would express it. Now, the mesentery is composed of two folds of the peritoneum, the smooth, shining, outer covering of the intestines.

The arrangement will be easily understood by the diagram in Fig. 60, which represents a section of the intestine with the mesentery. The cavity of the intestine, *a*, is lined by the mucous membrane represented by the inner circle. Next comes the muscular coat, and next the peritoneal, the outer, which, instead of making a circular tube, as the other two coats do, passes backward on both sides of the intestine, to make the mesentery, *b*. After being attached to the spine by means of cellular tissue, it is reflected off to pass over other portions of the intestine, as seen at *c*, *c*.

Between the two layers of the peritoneal membrane, in the mesentery, is considerable space, as seen at *b*. This space is filled up with blood-vessels, nerves, and lacteals with their small glands, soon to be described, all bound together by the common packing material of the body, the cellular tissue. You see, therefore, that the mesentery subserves more than one use. Besides fastening the whole tract of the intestinal canal to the spine, so as to guard it against accident, it acts as a secure medium for the passage of the blood-vessels and nerves to the intestines. And, besides, it contains the little tubes which convey all the nutriment into the blood for the growth and repair of the body.

124. Chyme, Chyle.—The chyme, as it passes into the small intestine from the stomach, has mingled with it the bile and the secretion of the pancreas. These are poured

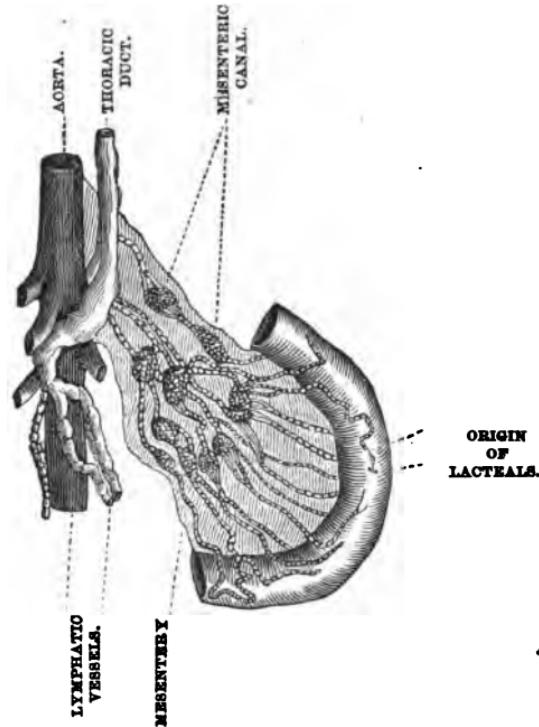
FIG. 60.



PLAN OF THE MESENTERY.

into the intestine at the point represented at 6, in Fig. 58. These secretions undoubtedly have some agency in separating the nutritious part of the chyme which is afterwards absorbed by the innumerable small vessels, called lacteals, situated in the mucous membrane. This nutritious part of the chyme is a milky fluid, called the *chyle*. The lacteals which absorb it are little tubes or ducts. These enter certain glands, called the mesenteric glands, and then pass on, as seen in Fig. 61, to pour their contents into the thoracic duct.

FIG. 61.

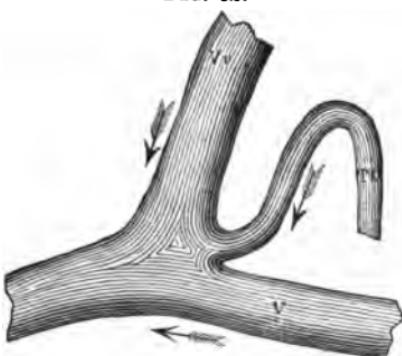


SECTION OF INTESTINE SHOWING THE LACTEALS.

125. Thoracic Duct.—This duct, which is about the size of a common quill, running up on the left side of the

aorta, the great artery of the heart, pours its contents into the junction of two veins at the top of the chest. The mode of the joining of this duct with these veins is calculated to facilitate the discharge of the chyle. As the two large currents in the veins, v and v, in Fig. 62, unite,

FIG. 62.



JUNCTION OF THE THORACIC DUCT WITH THE VEINS.

there is created, by the forward motion of these currents, a tendency to a vacuum at the angle at which they meet, the point where the thoracic duct, T. D., opens. There is, therefore, a suction power, as it is termed, exerted upon the fluid in this duct. The chyle, thus mingling with the blood, becomes a part of it.

126. Digestive Apparatus in Different Animals.—The digestive apparatus varies much in different animals, according to the kinds of food on which they live. As a general rule, the more the food differs in character from the animal itself, the more complicated and extensive is the apparatus. Thus, the herbivorous animals have a very long alimentary canal, and the beginning of it, the stomach, is a complicated organ. While, on the other hand, in the *carnivora*, the flesh which they eat being very much like their own flesh, and, therefore, not requiring a very complex process of assimilation, the stomach is a simple organ, and the alimentary canal is very short. In the sheep, for example, the alimentary canal is about twenty-eight times

the length of the body, but that of the lion only three times his length. In man, who lives on a mixed diet, the alimentary canal is about six times the length of the body.

127. Digestion in the Sheep.—The stomach is more complicated in animals that chew the cud than in any others. It has four distinct cavities, and a singular mechanism is called into operation in managing the food as it passes through them. In Fig. 63, you have a representation of the stomachs of the sheep, as they appear exteriorly. As the animal crops the food, it passes into the first stomach, which is little else than a great reservoir to hold and soak it. Then it passes into the second stomach, from which it is returned into the mouth. On being swallowed again, it passes from the *œsophagus* into the third, and thence into the fourth stomach. In Fig. 64, you see the interior of these four stomachs; and by the aid of this illustration I will describe the process of digestion in the sheep more particularly. You see the very large first stomach, or *paunch*, in which the food is accumulated. It is not yet masticated thoroughly, for the animal has swallowed it as fast as he could, and packed it away in this reservoir. From this it is passed, in small quantities at a time, into the second stomach, the *honeycomb*, so called from the peculiar network of folds in it. Here the food is rolled up into balls by the action of the muscular fibres in this network. Each ball of food is passed up through the *œsophagus* into the mouth, where it is chewed and thoroughly mixed with the saliva.

Then it is swallowed, and, as it passes from the *œsophagus*, instead of going into the paunch, as it did when swallowed the first time, it is directed through the groove seen in the Figure into the third stomach, the *manyplies*. This has many folds, like the leaves of a book, so that the food is exposed to a large surface in this cavity. It passes from this to the fourth stomach, the *reed*. Here, and here only, it is acted upon by the gastric juice. This, therefore, is the true stomach, all the other cavities furnishing only preparatory steps to the true process of digestion. It is from this fourth stomach that what is called the *rennet* is taken.

When fluid matter is swallowed, it goes directly into the second stomach, and not into the first, the paunch; so that, in the case of the sheep, the drink goes one way and

FIG. 63.

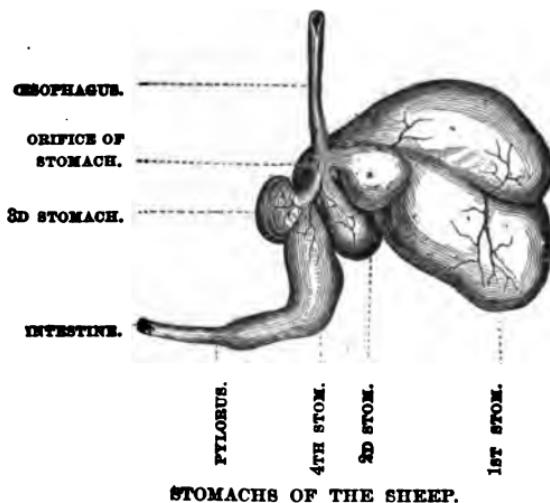
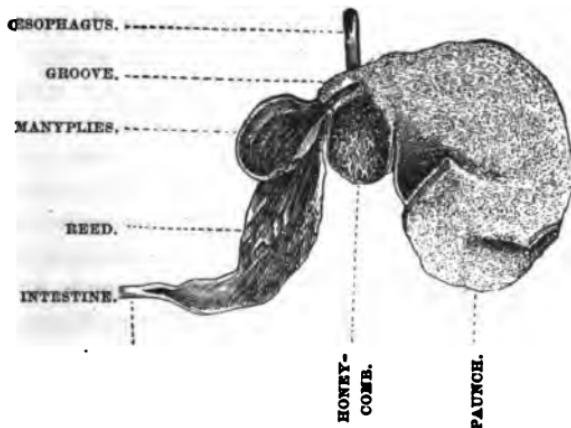


FIG. 64.



INTERIOR OF THE STOMACHS OF THE SHEEP.

the solid food another. And, what is still more singular, while the animal is a suckling, the milk passes into the fourth stomach through only the third, which has its folds so closed together as to form a mere tube to conduct it to its destination. And the great paunch and the honeycomb are wholly useless until the animal begins to crop its food for itself.

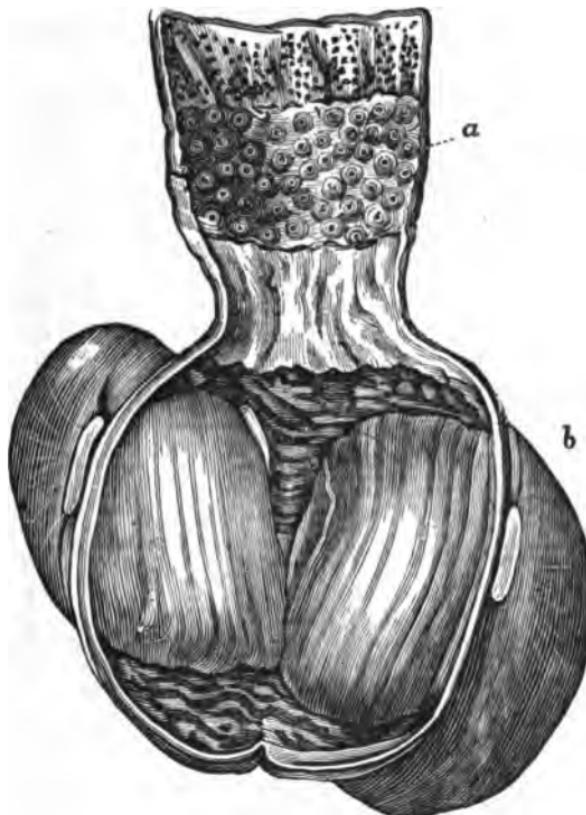
128. *Digestive Apparatus in Birds.*—In birds, the digestive apparatus is necessarily very peculiar, from the fact that they do not masticate their food. They have, on this account, an arrangement in the stomach itself for grinding the food. In the cavity called the gizzard are two opposing surfaces, made very hard, so that by rubbing together they bruise the grains; and while the food is thus ground, as between two millstones, the gastric juice is poured down upon it from above. This arrangement is seen in Fig. 65, which represents the digestive apparatus in the turkey laid open.

At *b* is the gizzard, showing the two hard surfaces, which are rubbed together by the stout muscles that make the great bulk of the organ. Above, at *a*, are the glands which pour forth the gastric juice. And above this part of the stomach there is, in all grain-eating birds, a large sac bulging out from the *œsophagus*, called the crop, which is a reservoir for the food, just as the paunch is in the ruminating animals. In those birds that live on flesh or fish there is no such grinding apparatus. The walls of the stomach are quite thin, and it presents no hard surfaces.

The kind of food, the mode of life, and the purpose which the animal is designed to fulfill, are the circumstances which govern the variations of the digestive apparatus. The proportion which the digestive apparatus bears to other parts varies very much; and in some of the lower orders of animals, the body seems to be all stomach. In such cases, the only appendages are those which seize the food and direct it into the orifice of this organ. This is the case with the hydra, represented in Fig. 1. And, what is very singular, the outside of the body of this animal

is just as capable of acting as a stomach as its inside. For when the creature is turned inside out, it will go on catching and digesting its food as usual.

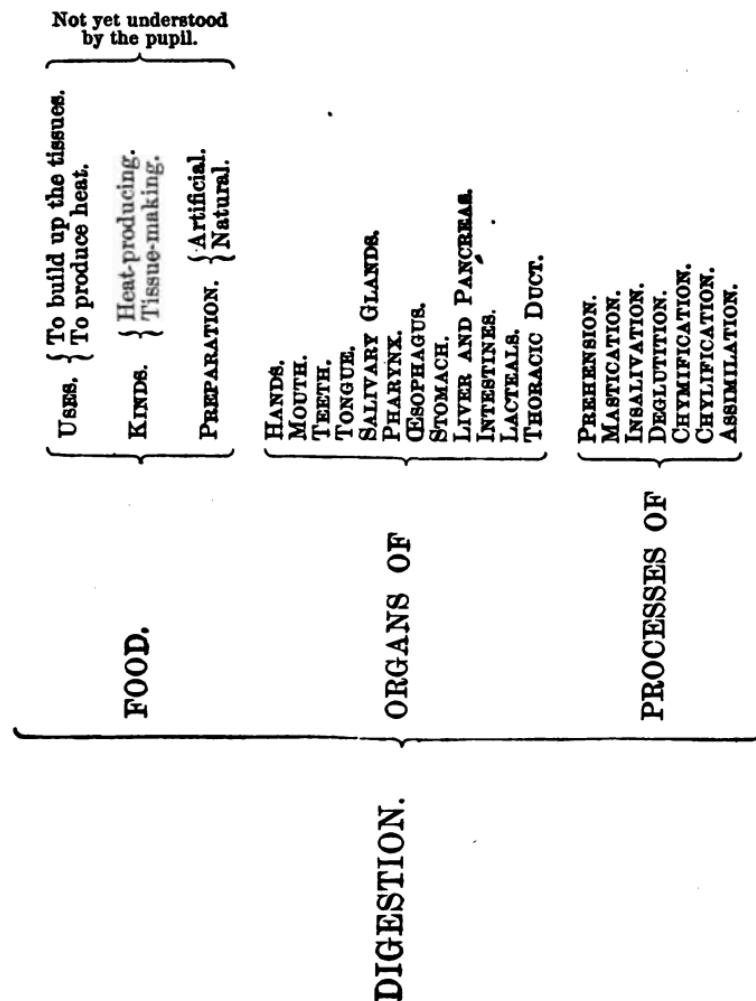
FIG. 65.



STOMACH OF THE TURKEY.

But, wide as the variations are in the digestive apparatus of animals, the same object is aimed at in all—the assimilation of nutrient substances to the animal, to produce a material from which its structure can be built and kept in repair. There is, therefore, much that is common to them all in the modes in which this object is accomplished. And even the analogy which exists between the

animal and plant, in regard to assimilation, does not relate to the fact alone, but in some measure to the modes in which the process is effected.



CHAPTER VIII.

CIRCULATION OF THE BLOOD.

129. Apparatus of the Circulation.—In the last chapter was described the manner in which the blood is made from the food. The blood, thus prepared, is circulated in every part of the body, that it may be used for the purposes of construction and repair. The apparatus by which this is done acts, as we have seen, as the common carrier of the material which is used everywhere in the body by the laborers, the builders, to whom it is thus brought.

This apparatus consists of several parts—a great central organ, the heart; the arteries, the tubes by which the blood is conducted to all parts of the body; the veins, other tubes, which bring the blood back to the heart; and the capillaries, a network of exceedingly minute vessels, through which the blood passes as it goes from the terminations of the arteries into the beginnings of the veins.

The blood goes from the heart through a large artery, called the aorta, which sends forth branches; and these divide and subdivide, so that the extreme arteries, through which the blood flows into the capillary network, are very minute. And the veins which receive the blood from this network to carry it back to the heart, are equally minute; but joining together, as they proceed toward the heart, they are at length all united into two great venous trunks, one from above and the other from below, which pour their contents into this organ.

The capillaries, taking their name from the Latin word *capilla*, a hair, are so small that they can not be seen by the naked eye. In any small cut, the blood which oozes out comes from multitudes of these vessels. They serve to hold the blood, while the formative cells, that construct

and repair the body, may select such materials as they need for their purposes.

130. *The Heart.*—The heart is a great central forcing and suction pump, in the midst of this circulating apparatus. When it contracts, it forces the blood out through the aorta and its branching arteries into all parts of the system. And when it enlarges or dilates itself, it, by suction, as it is termed, fills itself with the blood returning from the system through the veins.

131. *The Arteries.*—The arteries differ from the veins in their structure and arrangement. The arteries are firm though elastic tubes, while the veins are lax in their structure. The object of the difference is obvious. As the blood is forced into the arteries by the powerful action of the heart, it is necessary that they should be strong and firm.

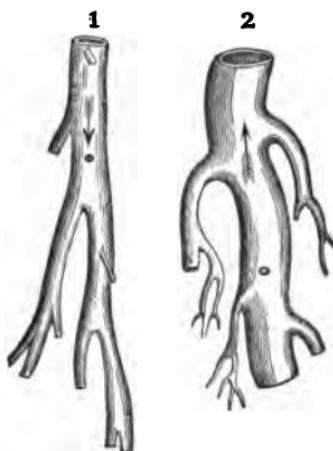
When a dilatation does occur in an artery, it is called an *aneurism*. But the arteries need to be firm, not only for the sake of security against rupture, but also that the force of the heart may propel the blood to the extremities of the arterial system. If the arteries were lax tubes, like the veins, the impulse would soon be lost in the yielding tubes, and the blood would move very sluggishly in the small arteries at a distance from the heart.

What we call the pulse, is caused by this impulse. If the arteries were lax tubes, the pulse would not be felt at any great distance from the heart. Instead of being distinct, as it now is, with every beat of the heart almost to the very extremities of the arterial system, it would be rendered confused by the yielding of the tubes, even quite near the heart, and at a distance from that organ it would be entirely lost.

Besides the firmness of the arteries, there is another circumstance which favors the free flow of blood through them. It is their mode of division. The branch of an artery leaves the main trunk at a sharp angle, making thus only a slight deviation from the direction of the main current; while, on the other hand, in the veins where the current flows in an opposite direction, the branch unites with

the trunk at nearly a right angle. This difference is represented in Fig. 66 ; 1 being the artery, and 2 the vein.

FIG. 66.



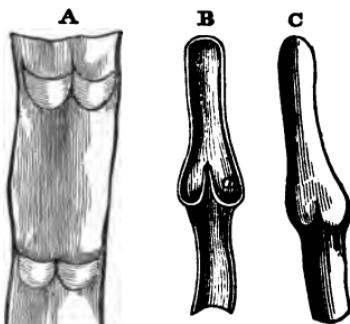
ARTERY AND VEIN.

132. The Veins.—The venous system has a much greater capacity than the arterial. That is, all the veins of the body are together capable of holding more blood than all the arteries are. And the blood moves very rapidly and directly from the heart through the arteries, but comes back to the heart quite slowly through the veins. Every thing is arranged to promote this rapid circulation through the arteries, while the venous system is calculated for a slow but sure progress of the blood back to the heart.

To secure this, valves, made of folds of the inner lining of the veins, are so arranged as to prevent the blood from flowing in the wrong direction. Fig. 67 represents a vein cut open so as to show these valves. A shows the valves as they appear when the vein is laid open and spread out; B, as they appear when the vein is simply laid open; and C represents the appearance of the outside of the vein where there are valves. The need which there is of this help to the circulation through the veins is obvious. The suction power of the heart is not competent, unaided, to move the

blood throughout all the lax venous system. These pocket-like valves, therefore, are made in the veins to assist the circulation there.

FIG. 67.



VALVES IN THE VEINS.

Every movement of the muscles or other parts about the veins tends to keep the blood in motion, and the valves serve to prevent this motion from taking the wrong direction. The difference in force and velocity with which the blood moves in the arteries and in the veins, is made manifest when they are wounded. The blood flows from a wounded vein in a slow and steady stream. From an artery it flows rapidly, showing the impulse of the heart in its jets, which correspond exactly with the pulse. Hence comes the danger in wounding an artery, while the wound of a vein is ordinarily attended with no danger.

133. Protection to the Arteries.—Accordingly, we find the arteries so placed, that they can not easily be wounded, while many of the veins are quite freely exposed.

The arteries are deeply seated, except in some few cases where this is impossible; but the veins are often superficially situated. You can see this, for example, in the bend of the arm. Some large veins appear there just under the skin, while the artery which supplies the arm is embedded among the muscles and tendons. In every part of the body, the most secure spot is chosen for an artery. Thus, at the knee-joint, the artery, instead of running over the surface

of bone, where it would be liable to be wounded, lies deep in the ham at the rear of the joint. The same is true of the elbow-joint, just alluded to, and of other parts of the body. Although there are arteries everywhere, they are uniformly so deeply seated, that it is only in a few localities that you can readily find one. You can feel one pulsating at the wrist, and another on the temple.

134. Mode of Stopping a Bleeding Artery.—It will be proper here to give some practical instruction, in regard to stopping the flow of blood from a wounded artery; as many lives have been lost from the ignorance of bystanders when such accidents have happened. Enveloping the part in cloths, which is so commonly done at such times, does no good, but only serves to catch and conceal the blood as it flows.

Pressure upon the artery, on that side of the wound which is *toward the heart*, will of course interrupt the supply of blood from this organ to the wound. Firm pressure with the thumb will do it. But the pressure must be made at the right point, that is, directly upon the artery. You may not, in all cases, press upon the right spot at once. If you do not, the blood will continue to flow. In this case press at different points, until you find the point at which you see that pressure stops the flow of blood from the wound. But you may not be able to find the right spot. If you can not, you can tie a slip of strong cloth or a handkerchief around the limb *above* the wound, and twist a stick in it until the bleeding stops. In one or the other of these ways, you can prevent the loss of blood until the surgeon arrives to take charge of the case.

135. Communication between Arteries.—Although there is no such free communication between arteries as exists between the capillaries, there is some amount of communication, and particularly in certain parts of the body. And it is well that it is so, for it sometimes helps the surgeon to save a limb, when he could not do it if there were no communication.

An artery has three coats, one of which is a strong fibrous

one. When this is thinned or ruptured, the other two coats bulge out, forming a pulsating tumor. And, as the blood is constantly pumped into this by the force of the heart, it enlarges, and at length it may burst, and the life of the patient be destroyed by the loss of blood. When an aneurism formed in a limb, as for example in the ham, the surgeon, in former times, used to save the life of the patient by amputating the limb above the aneurism. Putting a ligature round the artery above the aneurism would of course stop the flow of blood into it; but it was supposed that the limb would die, in that case, from the want of a proper supply of blood.

But it was found, at length, that this was not so; and surgeons now, in such cases, cure the disease, and save the limb too, by tying the artery. Immediately after the operation the limb is cold, and there is plainly very little circulation in it. But in a few hours the circulation becomes free, and in a little time it is as well established as ever. This is effected by the communications which exist between the branches which go off from the artery above the aneurism, and those which go off below it. It is obvious, however, that this would not be thoroughly effected if no change took place in the size of the communicating arteries. But this change does occur. Some of them become enlarged to meet the necessity of the case.

This is a most interesting fact; and so is also the fact—that these communications between branches of arteries are very common in the neighborhood of those places in the body where aneurism, from strains produced by violent and sudden motion, is peculiarly apt to appear. This same provision avails, of course, when aneurism is cured by pressure made upon the artery above it, a measure which modern surgery has found in many cases to be as effectual as tying the artery.

136. Action of the Heart Illustrated.—There have been great differences of opinion among physiologists in regard to the proportionate amounts of agency that the different parts of the apparatus have in carrying on the cir-

culation. The heart manifestly exerts the chief agency, both by its forcing and its suction power. You can get a clear idea of the manner in which it exerts these two forces in this way: Fill a ball of india-rubber, to which a tube is attached, with water, and immerse the tube in a vessel of water. If you press the sides of the ball together, some of the water is forced out into the vessel. This represents the contraction of the heart. If, now, you allow the ball by its elasticity to resume its round shape, the water rushes into it from the vessel. This represents the dilatation of the heart.

The dilatation of the ball results from its elasticity; and it is supposed by some that the dilatation of the heart results from the same cause, its contraction alone being produced by muscular action. Whether this is so or not, the dilatation is an active one, and the blood rushes into the heart from the veins by suction, as it is termed. The dilatation is so active that, as has been shown by experiments on animals, even a great amount of pressure is not able to prevent its taking place.

137. Action of the Capillaries.—But, great as the agency of the heart is, it is not true that it is the only moving power, and that the arteries and veins are mere passive conducting tubes. There are various phenomena which show that the arteries, the capillaries, and even the lax veins, exert a considerable agency in circulating the blood. We will merely allude to some of these phenomena.

Determinations of blood to particular parts show that the blood-vessels have an active agency in the circulation. In inflammation of any part, there is an increased activity of the particular portion of the circulating apparatus supplying that part. In the act of blushing, there is a local activity of the circulation somewhat independent of the heart. This is also true of the circumscribed flush of hectic.

138. Circulation in the Liver.—There is one portion of the circulation in which the active agency of the capillaries is especially manifest. The veins, receiving

the blood from all parts of the body, at length are all united into two veins, which empty their contents into the heart. But there is a very remarkable exception to this.

The veins which collect the blood from the viscera in the abdomen unite in one large trunk, called the *vena portæ*; and this, instead of pouring its contents into the large vein that goes up to the heart, divides, like an artery, into branches, which take all this blood to the liver for the manufacture of bile. Fig. 68 represents this circulation of the *vena portæ*. 1, 1, are the veins coming from the intestines; 2 is the trunk of the *vena portæ*; and 3, 3, are branches of it distributed in the liver.

FIG. 68.



CIRCULATION OF VENOUS BLOOD IN THE LIVER.

There must be, in this case, some propelling power in the capillaries, and some, also, in the veins. If there were not, another subordinate heart would obviously be needed in the *vena portæ*, to pump up the blood from all the veins of the abdominal viscera, and then to send it through all its branches into the capillaries of the liver.

139. Why the Veins are Full and the Arteries Empty after Death.—The veins have a less active agency in the circulation than any of the other parts of the apparatus. It is for this reason that commonly after death the veins are found quite full of blood, while the arteries are nearly empty. The apparatus of the circulation may be regarded as forming a circle of organs in this order—the heart, the arteries, the capillaries, and the veins. The blood is constantly going the rounds of this circle.

It is plain that, as the apparatus is about to stop, there must be an accumulation in the weakest, least active, and most relaxed of this circle of organs. The arteries and capillaries force the blood into the veins to the last moment of life. This effect probably extends no further than the smaller veins; but the heart, by its active dilatation, draws the blood from them into the larger veins. And as these two forces, at the two ends of the venous system, are at work up to the last moment, the whole of this system is filled with blood.

The fact that the large arteries are commonly found nearly empty of blood after death, gave the ancients the idea that air circulated in arteries, while blood circulated in veins. Hence the name, artery, is derived from two Greek words, signifying to hold air. And hence, also, by long established custom in common language, the blood is spoken of as running in our veins; and it would sound strangely if, in common and especially in poetical language, we should speak of it as running in our arteries also. Although there were from time to time some glimpses of the true idea of the circulation, it was not really developed and demonstrated till about two hundred and fifty years ago.

140. Changes wrought in the Blood.—A step farther in the development of the plan of the circulation will now be taken. We have seen that the office of the arteries is to conduct the blood to the network of capillaries, and that in the capillaries the blood has reached its place of destination where it is to be used. The formative cells, appended to the capillaries, take from the blood what they need for

their various purposes, and at the same time there is added to the blood refuse matter from the waste of the tissues.

The blood, then, is changed while it is in the capillaries. In the arteries it was red; but, after passing through the capillaries, it appears in the veins of a purple color. It is also as much changed in other properties. It is no longer fitted to nourish the body. It would even prove a poison to any organ into whose capillaries it should flow. If, for example, it, instead of bright arterial blood, should be sent to the brain, that organ would cease to do its office; insensibility would ensue, and life would soon be destroyed, if the flow of red blood could not be established.

141. Change takes place in the Lungs.—This purple blood, which comes back to the heart from the capillaries by the veins, must, therefore, be in some way changed to red blood, before it is again sent all over the system through the arteries. This change is effected in the lungs. As the purple blood returns to the heart, it is sent by the heart to the lungs, in order to be exposed to the air before it is sent again over the system. For this purpose there is a second circulation, and the heart is made a double organ; or rather, there are in effect two hearts for the two circulations, for the two sides of the heart have no communication with each other. The apparatus for all this is very complicated, but it can be made clear to you.

142. Course of Circulation.—First examine diagram 69, which is intended to represent merely the *course* of the circulation, without regard to proportionate size of parts, or to minutiae in the arrangement of the apparatus. Let *a* represent the right side of the heart, *c* the left side, *b* the lungs, and *d* the general system of the body. The arrows show the direction in which the blood flows. In all the shaded part the blood is venous or purple, and in the part not shaded it is arterial or red. We will now trace on the Figure the course of the circulation. We will start at *a*, the right side of the heart. The blood received here, of a purple color, from the whole body by the veins, is sent by the heart to *b*, the lungs. Here it changes to red blood,

and passes by veins back to the heart—but, observe, it is to the left side of the heart, *c*. It is now sent by this left half of the heart to all parts of the system, represented by

FIG. 69.

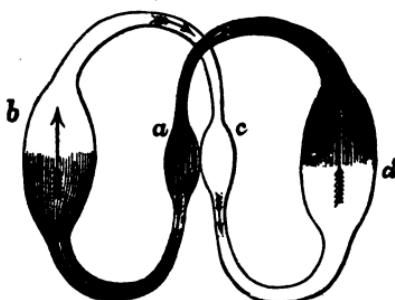


DIAGRAM SHOWING THE COURSE OF THE CIRCULATION.

d. Here, in the capillaries, it is changed to purple blood, and goes back by veins to the right side of the heart, *a*, the place where we started.

143. Two Circulations and Two Hearts.—You see, then, that there are two separate circulations, one through the general system, and the other through the lungs alone. In both circulations the blood is sent from the heart by arteries, and is brought back to it by veins. But notice that, while in the general circulation the red blood is in the arteries, and the purple in the veins, in the circulation through the lungs this is reversed—the red blood is in the veins, and the purple is in the arteries. So, also, while the change of the blood in the capillaries of the general system is from red to purple, in the capillaries of the lungs it is from purple to red.

144. Valves.—There are not only two sides or halves of the heart, separated entirely from each other, but each of these sides has two apartments, with valves or folding-doors between them, so arranged that the blood can pass one way through them, but not the other. There are also valves at the beginning of the great artery of the heart, the aorta. These are so arranged that the blood can go freely

out of the heart into the artery, but not a drop can get back from the artery into the heart. There are similar valves, also, at the beginning of the great pulmonary artery by which the purple blood is sent from the heart to the lungs.

In Fig. 70 is represented a section of the right side of the heart, for the purpose of giving you an idea of the relative size and position of the two apartments. The *auricle*, *a*, so called because a part of it has some resemblance to an ear, receives the blood from the whole system by two large veins, *b*, *b*, called the *venae cavae*. From the auricle it passes into the *ventricle*, *v*, which by its contractions sends it to the lungs through the pulmonary artery, *f*.

The valve between the auricle and ventricle is composed of three membranous sheets, which are held at their edges by small tendinous cords, *d*, just as a sail is held by the ropes at its corners. This valve permits the blood to pass from the auricle into the ventricle; but when it attempts to pass back from the ventricle to the auricle, it pushes back the sheets of the valve until their edges meet in the center, they being prevented from going too far back by the tendinous cords.

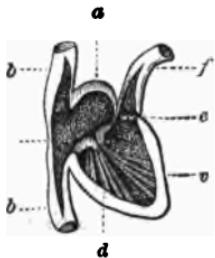
it pushes back the sheets of the valve until their edges meet in the center, they being prevented from going too far back by the tendinous cords.

There are also valves at *e*, the beginning of the pulmonary artery, which allow the blood to pass through them into the artery, but no blood can pass through them from the artery back into the ventricle.

145. Relation between the Auricles and Ventricles.—The auricle and ventricle act in this way in propelling the blood. When the auricle contracts, the ventricle dilates* to receive the blood from the auricle. The valves between them are open while this is taking place.

* This dilatation is an *active* one, as was stated in 136, when speaking of the heart as a whole. The ventricle does not dilate because the blood is forced into it, but the blood rushes into it because it dilates.

FIG. 70.



SECTION OF THE
RIGHT SIDE OF
THE HEART.

But the next moment the ventricle contracts and the auricle dilates. If the valves between them should now be open, the blood would be forced back into the auricle. But the membranous sheets of these valves shut upon each other as the ventricle contracts, and thus prevent the blood from going back. It therefore is discharged through the pulmonary artery, *f*, the valves there being open. When the ventricle dilates, the blood would, from suction, enter it from the artery as well as from the auricle, if the valves at the orifice of the artery should remain open. They are accordingly shut when the ventricle dilates.

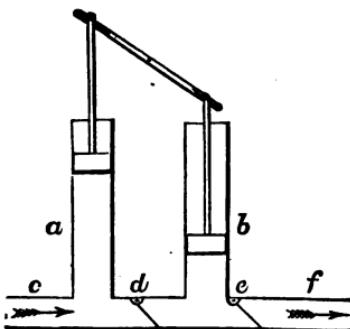
When, therefore, the auricle dilates and the ventricle contracts, the valves between the auricle and ventricle are closed, and those at the mouth of the pulmonary artery are open; and, on the other hand, when the ventricle dilates and the auricle contracts, the valves between them are open, and those of the pulmonary artery are closed.

Dr. Carpenter has a very good illustration of the relation of the actions of the auricle and ventricle, in a representation given in Fig. 71. The apparatus which is represented consists of two pumps, *a* and *b*, the pistons of which move up and down alternately. These are connected with a pipe, *c,f*, in which there are two valves, *d* and *e*, opening in the direction of the arrows. The portion *c* of the pipe represents the venous trunk discharging its blood into the heart, and the portion *f*, the artery which is the outlet for the blood. The pump, *a*, represents the auricle, and the pump, *b*, the ventricle. When the piston in *a* is raised, the fluid enters through *c* to fill it by suction, as it is termed. When, now, its piston is lowered, the fluid is forced through the valve *d* into the pump, *b*, (which represents the ventricle,) whose piston is at the same time raised to receive it. And when the piston in *b* is lowered in its turn, the fluid being prevented from returning into *a*, by the valve *d*, is forced through the valve *e* into *f*, representing the discharging tube, the artery. At the same time, a fresh supply of fluid is received into *a* by the raising of its piston.

The auricle and ventricle of one side of the heart, the

right side, have been described. The left side is constructed very much in the same way. You will observe, in Fig. 70, that the ventricle is much more capacious than the auricle.

FIG. 71.



The auricle is indeed the antechamber to the ventricle. The ventricle, too, has much thicker walls. It is made very strong, because it does the principal part of the work. The size of the whole heart is about that of the closed hand of the individual.

146. Valves of the Aorta.—Your attention is now called to a more particular view of the valves of the heart. We will take, first, the valves which are at the beginning of the aorta, the great artery of the body, going out from the left ventricle. These are very much like the valves of the veins seen in Fig. 67. There are three of them. They are like little pockets arranged around the orifice of the artery, and looking toward the tube of the artery.

Of course, when the ventricle contracts, and forces the blood into the artery, these pockets are pressed by the blood flat against the sides of the artery. But when the ventricle dilates, and the blood attempts to go back from the artery into the ventricle, it gets into these pockets, and bulges them out toward the heart, and thus the mouth of the artery is closed. But if these pocket-like valves had plain curved edges, they would not effect a perfect closure. There

would be a little space in the very middle of the orifice of the artery which would be left open. This is made plain by Fig. 72, which represents the orifice of the artery with its closed valves, as it would appear seen from the interior of the heart, if the three valves had plain curved edges. There would be a space left between them. But this difficulty is remedied by a very simple contrivance. A little fleshy projection is placed upon the middle point of the edge of each valve, of such a size that the three projections together just fill the space A.

When, therefore, the valves are closed, no blood can go back from the artery into the ventricle. This arrangement is shown in Fig. 73, in which the aorta, *a*, is laid open and spread out, so as to show the three valves with their projections on the edges. At *b* and *c*, are the openings of the two arteries that supply the walls of the heart with

FIG. 72.

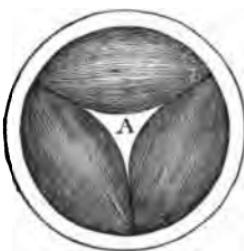
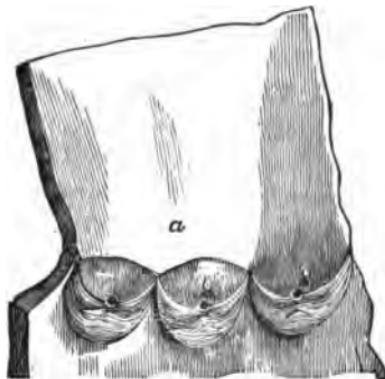


FIG. 73.



VALVES OF THE AORTA.

blood for their growth and repair, for the heart is constructed and repaired from its own blood. The valves at the orifice of the pulmonary artery are arranged in the same manner as those which are at the orifice of the aorta.

147. Arrangement of the Valves between the Auricles and Ventricle.—The valves which are between the auricles and the ventricles, are folds of strong white membrane, their edges being held by numerous small tendinous cords. And these cords are manned, as we may express it, by muscles attached to the walls of the heart. The office of these muscles is to hold on to the cords that are fastened to the edges of the valves, and prevent these sheets of membrane from flapping back too far when the powerful ventricle contracts. If this were not done, the consequence would be, that when the ventricle contracts with prodigious force, as sometimes occurs when the circulation is in a state of great excitement, the light tendinous fastenings would be ruptured by the pressure of the blood upon the valves. As arranged, however, the strong but yielding muscular bundles, to which these tendons are attached, regulate with great exactness the closing of the valves.

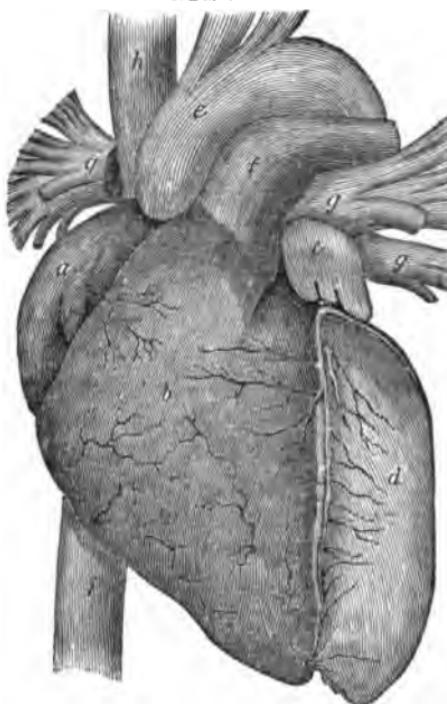
148. No Valves at the Openings of the Venæ Cavæ. Why?—In looking at Fig. 70, observe that, while there are valves between the auricle and ventricle, and at the mouth of the artery going out from the ventricle, there are none at the openings of the two *venæ cavae*, the veins that pour their contents into the auricle. Why is this? Why is there no need of valves here to prevent a regurgitation into these veins when the auricle contracts? It is because that, as the auricle contracts, there is at the same time the dilatation of the strong ventricle, making, of course, a suction in that direction so powerful as to counteract most fully any tendency to regurgitation into the veins.

149. General View of all the Parts of the Heart.—Having thus examined the heart in detail, you are now prepared to look at it as a whole. Fig. 74 presents a front view of the heart, in which *a* is the right *auricle*, receiving the purple blood from the whole body by two large veins, *h* and *i*, called the *venæ cavae*; *b* is the right *ventricle*, that receives the blood from the right auricle, and sends it to the lungs by the *pulmonary artery*, *f*; *c* is the

left auricle, which receives the red blood from the lungs, by the pulmonary veins, *g*, *g*, *g*; *d* is the left ventricle that receives the blood from the left auricle, and sends it all over the body through the *aorta*, *e*.

You observe that you see but a part of the *left* auricle and ventricle, they lying partly behind the *right* ventricle.

FIG. 74.



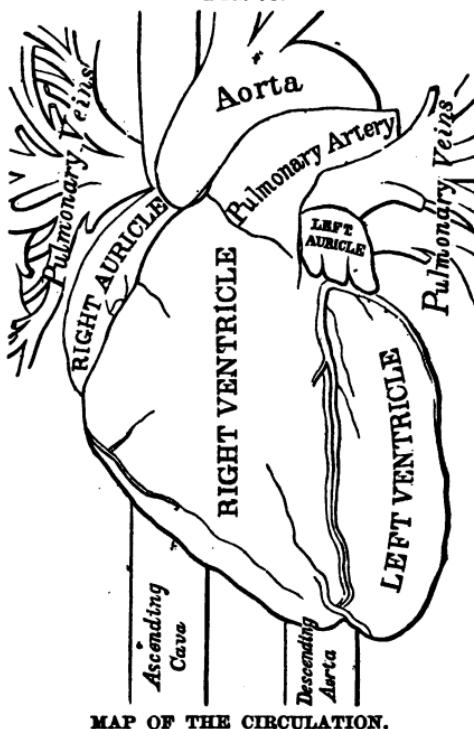
FRONT VIEW OF THE HEART.

You do not see the very beginning of the *aorta*, for, as it rises from the left ventricle, it is at first concealed behind the top of the right ventricle and the beginning of the pulmonary artery. It then forms an arch, from which it sends forth branches to the head and upper extremities; and it afterwards passes down behind the heart, to supply with its branches the trunk of the body and the lower extremities.

In the line of division between the two ventricles, *b* and *d*, you see one of the *coronary* arteries, as they are called, which, coming from the beginning of the aorta, supply the walls of the heart with blood.

150. Course of the Blood through the different Cavities of the Heart.—To make you quite familiar with the relations of the different parts of this complicated organ, and with the course of the blood through its different apartments, in Fig. 75 is given a map of the

FIG. 75.



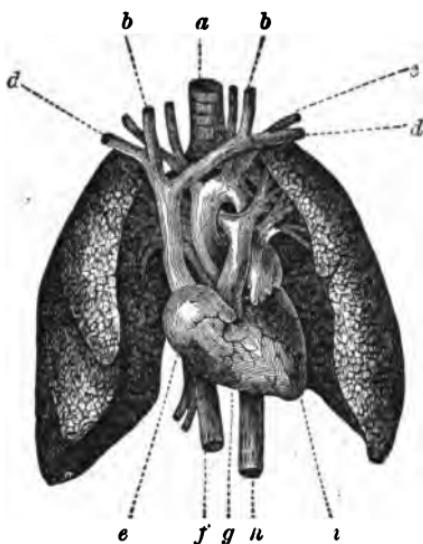
MAP OF THE CIRCULATION.

heart, with the names placed upon the parts. The dark blood is received from all parts of the body by the *væna cavae*—from the parts above by the descending cava, and from the parts below by the ascending cava. These veins pour the blood into the right auricle. From this it passes into the

right ventricle, which sends it by the pulmonary artery to the lungs. From the lungs it returns by the pulmonary veins to the left auricle. It then passes into the left ventricle, from which it is sent by the aorta to all parts of the body.

151. Relation of the Heart to the Lungs.—In Fig. 76 is represented the heart, situated between the two lungs, with the arteries which carry blood from it, and the veins which pour their blood into it. The lungs are represented as being drawn apart to the right and left in front, so as to expose fully the heart and its vessels. The sac containing the heart, and the packing cellular tissue, are re-

FIG. 76.



LUNGS, HEART, AND PRINCIPAL BLOOD-VESSELS.

moved, so as to lay the heart and its vessels bare. At *a* is the trachea or wind-pipe; on each side of it are the two arteries, the carotids, which go to the head; *c* is the artery which goes to the arm; *b, b*, are the jugular veins coming from the head, *d, d*, the veins from the arms, all emptying their contents, as you see, into the descending cava; *e* is the right auricle, receiving the blood from the two cavæ; *f* the

ascending cava; *g* the right ventricle, *i* the left ventricle, and *h* the descending aorta.

152. Causes of the two Sounds of the Heart.—The harmony of action between the two sides is preserved by having the two auricles act together, and the two ventricles act together. And this action produces two sounds, which may be heard by applying the ear to the left side of the chest. The first sound is rather a prolonged and heavy one, the second is light and quick. The first sound occurs when the strong action of the heart is performed, that is, when the ventricles contract. It is owing to several causes. One of these is the impulse of the heart against the walls of the chest.

Another is the flapping together of the valves between the auricles and the ventricles, to prevent the blood from regurgitating into the auricles, when the ventricles contract to force out their contents. The light and quick second sound is caused principally by the flapping together of the valves at the mouths of the aorta and the pulmonary artery when the ventricles dilate. The pulse is produced by the impulse given to the blood by the contraction of the ventricles. There is, therefore, a pulse in the arteries of the circulation through the lungs, as well as in those of the circulation through the general system. Wherever there is an artery there is pulsation.

153. Movement of the Heart as a Whole.—The impulse of the heart against the front wall of the chest on the left side is easily explained. The aorta, in going from the heart, makes an arch upward and backward, to go down in front of the spine; and it is the tendency to straighten out, produced in this arch by the force of the blood thrown into it by the ventricle, that causes the throwing of the heart forward by a spring. This is easily seen as illustrated by Fig. 77, in which *a* is the spinal column; *b*, the front wall of the chest; *d*, the heart; and *c*, the arch of the aorta. When the heart throws the blood into this arched tube, tends to straighten it; but as the aorta is fastened to the fixed spine behind, there can be no impression made in

that direction. The straightening of the arch must therefore occur in the other direction, to the front; and the heart is thrown a little forward, as represented by the dotted lines. The change of position thus produced is indeed but slight, but it is sufficient to cause the impulse.

154. Pericardium.—The heart is inclosed in a sac, called the *pericardium*, which, at its upper part, is fastened all around the vessels that proceed from the heart. This sac is lined on the inside by a serous membrane, which also lines the outside of the heart, being reflected over upon it from the pericardium. This membrane forms, therefore, a sac without any outlet. This is made plain by Fig. 78. In this diagram, showing the plan of the serous membrane of the pericardium, *a, a*, are the auricles; *v, v*, the ventricles; *b, c*, the vessels proceeding from the heart; *p* the serous membrane lining the outside of the heart; *p'*, the same membrane reflected from the upper part of the heart and

FIG. 77.

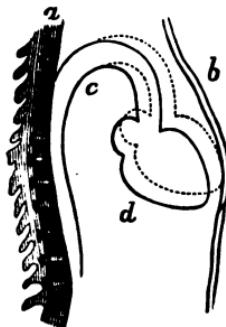
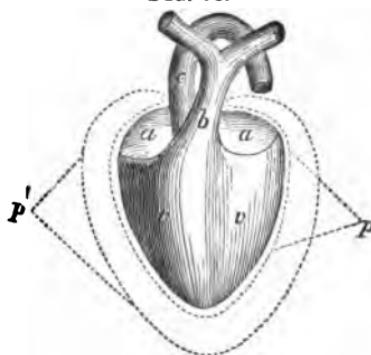


FIG. 78.



PLAN OF THE PERICARDIUM.

covers the inside of the pericardium. Now, this sac is kept moist by a fluid exuding from its whole surface, so that,

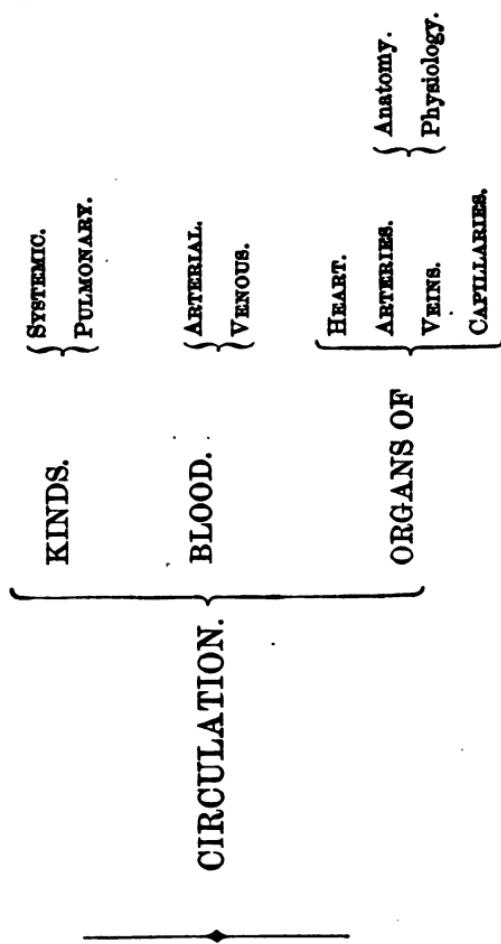
as that part of it which covers the outside of the heart, in the motions of that organ, rubs against that part which lines the pericardium, the lubrication prevents any injury from the friction. This lubricating fluid is continually renewed, the exhalants and the absorbents balancing each other in their action. When the exhalants secrete more fluid than the absorbents can take up, the excess accumulates, making what is called dropsy of the heart.

155. Action of the Heart Involuntary.—The heart, as you have seen, is a complex arrangement of muscles. And these muscles are wholly involuntary; that is, they are not at all under the direct control of the will. No one can, by an exercise of the will, make his heart beat slower or faster. As will be seen in another chapter, this organ is kept at work by its nervous connection with the spinal marrow. It has no repose, as the voluntary muscles have, unless you call the intervals between the contractions and dilatations of its several parts intervals of repose.

The amount of work which it does in a lifetime is enormous. The heart of an adult beats, that is, each one of the four chambers of this organ dilates and contracts, about 70 times in a minute. This would make 100,800 times in 24 hours, 36,792,000 times in a year, and 2,575,440,000 times in a life of 70 years. In children, the action of the heart is much more rapid, and in disease it sometimes reaches in them 160 or even 200 beats in a minute.

The two circulations of the general system and of the lungs are ever going on. The blood is ever moving in all the cavities of the heart, in every artery, and vein, and capillary. It never stops till it is arrested by death.

NOTE.—The heart moves in an ordinary lifetime, more than a quarter of a million of tons of blood. It can raise its own weight 20,250 feet in an hour. An active climber can accomplish only 4,000 feet an hour, or one-twentieth of the work done by the heart, while the best locomotive can raise its own weight through only 2,700 feet in the same time.



CHAPTER IX.

RESPIRATION.

156. Organs of Respiration.—The lungs are spongy bodies, filling up a large part of the chest, and surrounding the heart. They are, in common language, the

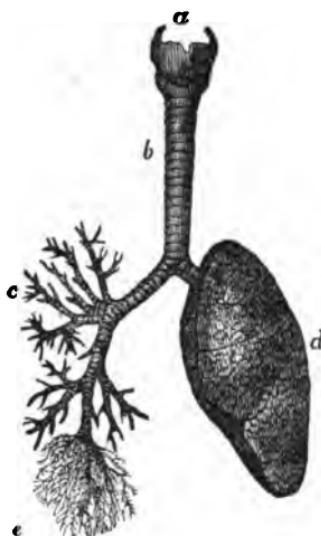
lights; and you can learn what they are in man by observing the lights of other animals. They are composed chiefly of air-tubes, air-cells, blood-vessels and nerves, packed together with the common packing material of the body, cellular tissue. The spongy lightness of the lungs is owing to the air-cells or vesicles. You can get some idea of the proportion of these cells to the solid part of the organs if you inflate the lungs of some animal, as the sheep or calf, by blowing into the windpipe. These cells are exceedingly minute, and in them a marked change is effected in the blood.

The capillaries holding the blood, branch out on the walls of the cells, and the blood is acted upon by the air through the pores of the vessels. The process of respiration introduces the air freely into these cells. The air enters through the windpipe, which branches out into tubes called bronchia which divide and subdivide, till they become very minute, and then end in the air-cells. These cells are estimated to be about the $\frac{1}{100}$ th of an inch in diameter. Some calculations have been made in regard to the extent of surface which they would all make if they could be spread out in one sheet. There is of course no great accuracy in such calculations; but we can readily see that the aggregate surface must be immense, and, therefore, the blood is thus very extensively exposed to the action of the air. In Fig. 79 is represented the lung of one side, *d*; the branches of the bronchi of the other lung, *c*, at the lower part of which, *e*, they are represented as they branch out minutely to open into the air-cells; *b* is the trachea or windpipe, and *a* is the larynx at the top of it. It is through a chink called the glottis, in the larynx, that all the air passes as it goes into and out from the lungs. This will be particularly described hereafter.

157. Relative Situation of the Heart and Lungs.—In Fig. 76, in the last chapter, you see represented the relative situations of the heart and lungs, the lungs being somewhat separated, however, from the heart, to the right and left, in order to show that organ fully. In their natural position they are close to the heart, and cover

up all of it, except a small portion in front and to the left side, where its beating is so plainly felt. Both the heart

FIG. 79.



LUNGS AND AIR-TUBES.

and the lungs are suspended in the chest to the upper part of the walls of this cavity, and are fastened also to the spinal column in the rear. The large vessels of the heart, and the bronchi of the lungs, serve as the principal means of suspending these organs, as is shown in the Figure.

158. Pleura.—The lungs are covered by a white, shining membrane called the *pleura*, which also lines the inside of the walls of the chest. This is always kept lubricated by a watery fluid, so that, as the lungs expand and the chest moves, the friction will be attended with no inconvenience or injury.

159. The Lungs not Connected to the Walls of the Chest.—You may perhaps ask why, as the lungs follow the walls of the chest in its expansion, they could not have been fastened to these walls throughout their whole

surface. The principal reason probably is that, if this were the case, the intimate vascular connection which would exist between the walls of the chest and the lungs, would expose the delicate texture of these organs more frequently to injury from external violence. As it is now, the effusion, or the inflammation, consequent upon a blow on the chest, is not apt to affect the lung in the neighborhood, because it has no *direct* connection with it by nerves and blood-vessels.

160. Mechanism of Breathing.—You are now prepared to see by what mechanism the air is alternately introduced to and expelled from the lungs. The chest incloses a large space, which can be made much greater by certain movements of its walls.

It is this expansion of the cavity of the chest, effected by certain muscles, which causes the air to rush into the chest through the trachea, just as air rushes into the bellows when the space within is enlarged by the separation of their walls.

In Fig. 80 is shown the framework of the chest. At *b*, *b*, is the spinal column, the grand pillar supporting the walls of this cavity. The ribs, *c*, *c*, go from this with a large curve round to the breastbone, *a*, in front. The ribs, however, do not join directly with the breastbone, but there are cartilages intervening, as seen in the Figure. The collarbone goes from this breastbone across to the top of the shoulder. The ribs are twelve on each side. The lowest two are attached only to the spine, and are called floating ribs. The whole is so constructed as to allow a very considerable expansion of the cavity. As the chest is kept in constant motion, lightness in its walls is an object of some importance; and, at the same time, it is necessary that the structure should be a strong one, in order to effectually guard the lungs from injury. Both of these objects are secured, by having the walls in front and at the side composed of so many bones, well bound together by the muscles which move them. The cartilages which connect the ribs to the breastbone are a great safeguard. They give elasticity to

the structure as a whole, and the ribs are not very liable to be broken, because of the yielding of the cartilages with which they are connected.

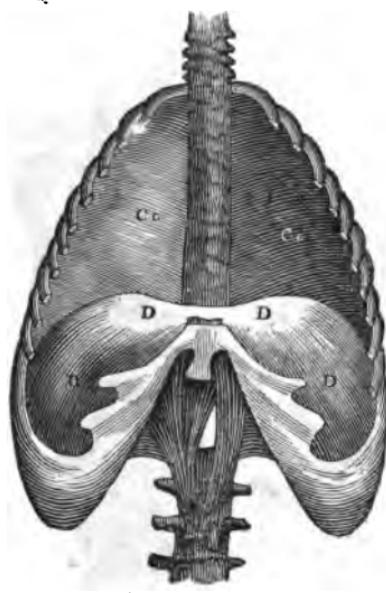
FIG. 80.



161. Framework of the Chest.—This framework is filled out with connecting material, chiefly muscles, which effect the expansion of the chest in inspiration. First, there is a large expanse of muscle and tendon called the *diaphragm*, stretching across the lower part of the chest and separating its contents from the contents of the abdomen below. The edge of this muscle is fastened to the spine behind, to the end of the breastbone before, and all around the lower ribs. It is arched upward; and against its concave surface press upward the liver and stomach, while the lungs and the heart press downward against its convex surface. The diaphragm is represented in Fig. 81. The ribs are cut away in front, so as to give a front view of the cavity of the chest, C, c, the lungs and heart being entirely removed. D D is the diaphragm, very high in the central portion, which is

tendinous, but descending very low at its edges at the sides and in the rear.

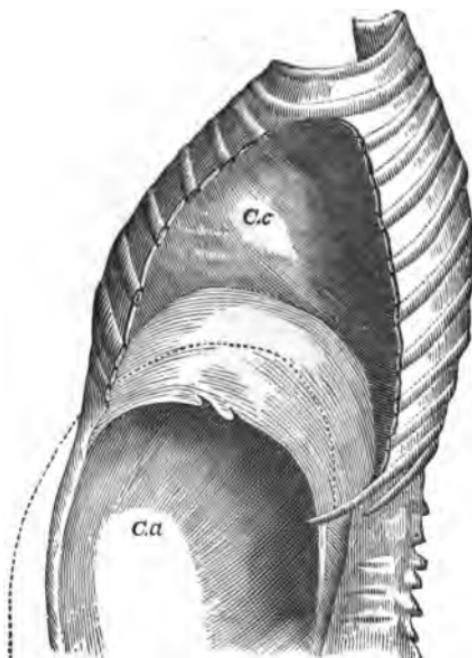
FIG. 81.

DIAPHRAGM,
Front View.

162. Inspiration and Expiration.—The Diaphragm.—If all the muscular fibres in the diaphragm contract, the arch will be flattened, and thus the room in the chest will be enlarged. To occupy this additional space the air rushes in through the windpipe. This is *inspiration*. In *expiration*, the reverse movement takes place—the arch of the diaphragm rises, and compressing the lungs, forces the air out of them through the trachea. In inspiration, as the diaphragm is flattened, it pushes down before it the stomach, liver, &c., and hence the pressing out of the abdomen, which is so sensibly felt, if the hand be placed upon it during the act of inspiration. In expiration, on the other hand, the abdominal walls retreat inward. These two opposite states of the arch of the diaphragm, and of the walls of the abdomen, are represented in Fig. 82. It is a side view, the

ribs being cut away. C c is the cavity of the chest, and C a, the cavity of the abdomen. The diaphragm and the abdomen are represented as they are in expiration. The dotted

FIG. 82.



DIAPHRAGM.

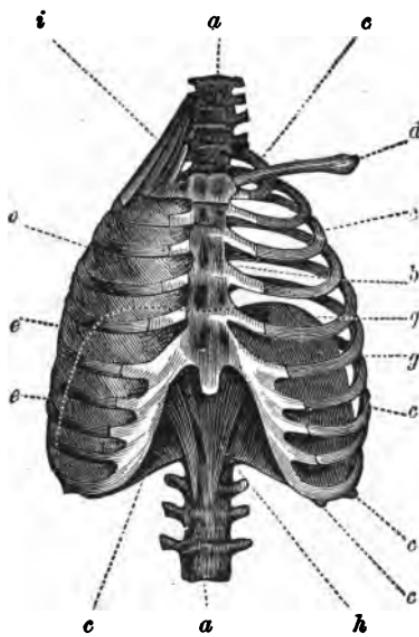
Side View.

line marks the flattening of the arch of the diaphragm, and the projection of the abdomen, as they occur in inspiration. It is supposed that in ordinary expiration, there is little, if any, muscular action—that, as the diaphragm, which in inspiration pushed down the stomach and liver, and thus thrust out the walls of the abdomen, ceases to contract and relaxes, the mere elasticity of the parts below, and especially of the abdominal walls, restores the former condition of things, and so the diaphragm is carried upward, and expiration results. When, however, the expiration is at all forcei-

ble, it is produced in part by the action of the muscles of the abdomen and some of the muscles about the chest.

163. Other Muscles, besides the Diaphragm, Act in Inspiration.—While this dome-shaped muscle, the diaphragm, is the principal agent by which the chest is enlarged, there are other muscles which render assistance. In Fig. 83, *a* is the spine; *c, c, c*, the ribs; *b*, the breastbone; *d*, the collar-bone; *g*, the diaphragm. You observe, on the

FIG. 83.



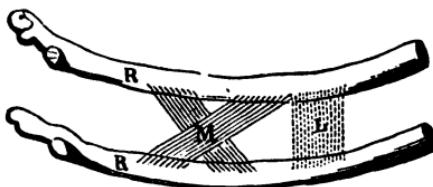
WALLS OF THE CHEST.

right side of the chest, certain muscles, *i*, extending from the spinal column in the neck to the first rib. When these contract, the effect is to raise the first rib, and all the others being attached to it, of course follow. As the ribs in Fig. 80 slant downward from the spine toward the front, the result is, that all the ribs are carried together forward and upward. The result is the more effectually secured by

muscles which pass from rib to rib, as seen at *e, e, e, e*, Fig. 83. In this Figure, the ribs, *c, c, c*, are left bare on the left side, to show the arch of the diaphragm, *g*, the dotted line indicating it on the right side.

164. Arrangement of Muscles between the Ribs.—There are two layers of muscles connecting the ribs, the fibres of which cross each other, as represented at *M*, in Fig. 84. *R R* are parts of two ribs. The spaces

FIG. 84.



between the ribs are filled with muscular fibres, arranged as represented in the Figure.

These muscles between the ribs not only help to raise all the ribs as a body, but they bring each rib nearer to the one above it. This increases the expansion of the chest, especially as the ribs are so joined to the spine, that if a rib be moved upward, it must be carried outward as well as forward. It is evident that by the operations of these muscles in the neck and between the ribs, the diameter of the chest will be increased from front to rear, and also from side to side.

The chest is expanded, then, by two motions—by flattening the arch of the diaphragm, and by raising the ribs. In ordinary quiet respiration, this expansion is effected chiefly by the diaphragm. But when there is a call for more active respiration, as in violent exercise, the muscles which raise the ribs act strongly, and hence the heaving of the chest, as it is called. Their action is violent when from disease, as in asthma, for example, it is difficult to introduce sufficient air into the lungs.

165. Result of an Opening through the Wall of the Chest.—The lungs, heart, &c., accurately

fill the chest in all the variations of size to which its cavity is subjected in respiration. For, when the chest is expanded, the spongy lungs swell out to follow its walls, and the air rushes in through the trachea to fill the expanding air-cells. If, now, there were an opening through the walls of the chest, communicating with the outside of the lung, when the chest expanded, the air would rush in at this opening as well as through the trachea, and the lung would be compressed in proportion to the freeness of the opening. This has sometimes occurred from disease and from wounds. If a free opening were made at the same time in both sides, both lungs would be compressed, and death would be produced by suffocation, as really as if some obstruction in the windpipe prevented the air from entering the lungs.

166. Change in the Blood effected in the Air-cells.—As has been said, the change in the blood, from purple to red, is effected in the air-cells. The blood and the air are brought very near together for this purpose; and yet they are kept entirely separate. It is supposed that the air in the cells acts upon the blood through the pores of the vessels containing it, which branch out on the walls of the cells; for if dark venous blood be inclosed in a bladder, the air will act through the pores of the bladder, and gradually change the outer portion of the blood to a red color.

167. Variable amount of Work done by the Air-cells.—These air-vesicles, then, do an important work. The change which is effected in them is immediately essential to the continuance of health, and even of life. If the air be in any way shut out from them death occurs at once. And so important is it that they should do their work well, that extraordinary provisions are made to secure an abundance of room for them under all circumstances. For the cavity of the chest, as you have seen in this chapter, can be expanded to a very great extent. It would indeed be difficult to conceive how a greater range of expansion could be secured. As the air-cells are called upon to do more work at some times than at others, there are special provisions for

a larger dilatation of the chest than is required in ordinary quiet respiration. Thus when, from violent exercise, the blood is coursing rapidly through the lungs, and more air is therefore needed to change it to red arterial blood, the chest is largely expanded by calling into action muscles, which do but little, if any thing, in ordinary breathing.*

168. Injury done to the Air-cells by Compression of the Chest.—As the apparatus of respiration is so especially arranged to secure room for the lungs under all circumstances, it must be very deleterious to the health of the body to interfere with this arrangement. If the expansion of the chest in breathing be limited by any pressure, every air-cell must be embarrassed in doing its part in changing the blood.

Either all of them must be unduly contracted, or some of them must become obliterated, so that there will not be as many vesicles as there should be. In either case, the organ is disabled in proportion to the amount of the compression. The blood is not so good as it would be if there were enough vesicles, and they could perform their work without constraint. The vigor of the system is therefore lessened. And, besides, the lungs themselves, from this unnatural confinement, are especially liable to disease.†

Vigorous exercise undoubtedly causes much injury to lungs that are thus confined. If the chest be left free to ex-

* It is a curious fact that the mechanism of respiration is somewhat different in the two sexes. In men the diaphragm takes the larger share in the process, the upper ribs moving comparatively little; in women the reverse is the case, the respiratory act being largely costal.
—HUXLEY.

† The volume of air which remains in the lungs (Residual air) after a forced expiration, is from 75 to 100 cubic inches. An equal additional volume (Supplemental air) remains in the chest after an ordinary expiration.

In ordinary breathing, 20 to 30 cubic inches (Tidal air) pass in and out. A forced inspiration will add 100 cubic inches (Complementary air) to the volume. Then after a forced inspiration the lungs contain $100 + 100 + 30 + 100 = 330$ cubic inches of air. After an ordinary inspiration $100 + 100 + 30 = 230$ cubic inches.

pand to its fullest extent when occasion requires, this injury is avoided. For when the strongly and rapidly contracting heart pumps the blood in such quantities into the lungs, the widely expanding chest draws in the due amount of air to change the extra amount of blood. All the air-vesicles are ready to do their duty, and, therefore, no violence is done to the delicate texture of the lungs.

But if these organs be compressed, the dilatation of those vesicles that are not obliterated, in the midst of the commotion of the difficult respiration, is very unequally effected, and some of them are stretched beyond their proper dimensions. At the same time, the blood must be here and there obstructed in its passage through the lungs, producing what is termed congestion. And if this violence be frequently repeated, permanent disease will be the result.

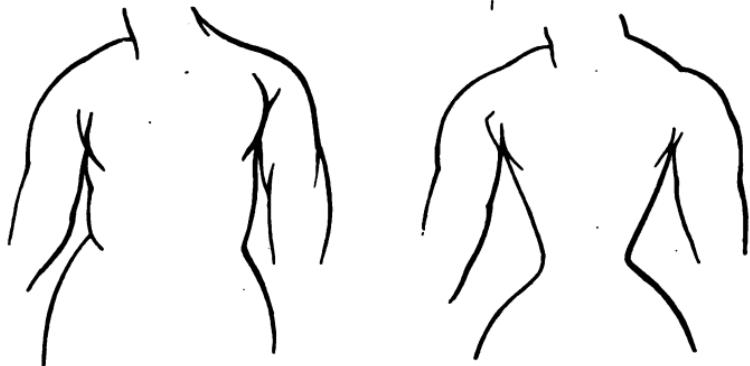
From the considerations in the last two paragraphs it is manifest, that the interference with the due expansion of the lungs, which so commonly results from the modes of dress in the female sex, must be one of the prominent causes of consumption, to say nothing of other diseases arising from this cause.

This interference is effected in two ways—chiefly by compression of the chest directly, but also by the pressure which the load of clothing hanging from the waist must make upon the upper part of the abdomen. This latter cause interferes with that forward movement of the abdomen which is necessary to the flattening of the arch of the diaphragm in the act of inspiration.

The extent to which compression of the chest is sometimes carried is seen by comparing the two outlines in Fig. 85. One is an outline of the Venus de Medicis, the universally recognized beau ideal of beauty of form in the female, and the other is an outline of the form of a lady with an artificially small waist. In Fig. 86 is represented the framework of the chest of its natural size, and as it is sometimes contracted by fashion. The Figures representing the contraction of the chest may appear at the present time as caricatures, for a very small waist is not considered now to be so

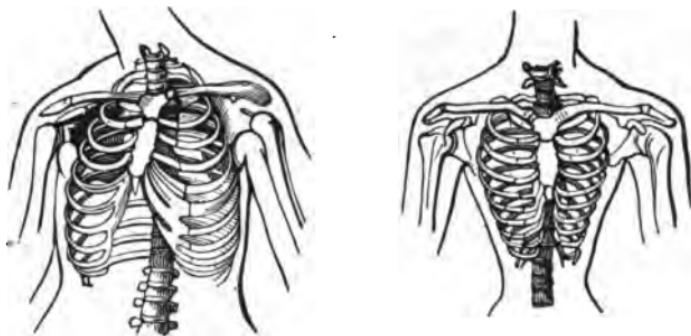
essential to beauty in the female form, as it was twenty-five years ago. The truth, as uttered by medical men, has had some effect. But the evil is remedied only in part. The chest of the female is still too much begirt, in obedience to

FIG. 85.



the tyranny of fashion, to allow of the free expansion to secure which such special pains are taken by nature. The

FIG. 86.



evil begins in childhood. The chest is moulded during its growth to the shape which fashion prescribes. It could not be done after the chest has attained its full size. The torture of the compression necessary to do it could not be endured.

In childhood, therefore, while the boy's chest is left to grow in its natural shape and dimensions, the girl is begirt

so tightly as to embarrass her respiration, because nature is too ungenteelly large in her patterns.

169. Cause of Death in Drowning.—It is the interruption of the change which is effected by the air upon the blood in the lungs, that produces death in drowning. The very common supposition, that considerable water gets into the lungs in drowning, is erroneous. Very little water ordinarily gets in—not enough to occasion any embarrassment.

The difficulty is, that the air is kept out, and not that the water gets in. The drowning person makes attempts to inspire, but the moment that the water reaches the epiglottis, the door of the windpipe, it causes at once, by its irritation, a spasmotic closure of the epiglottis, so that almost no water is introduced. In the mean time, the purple blood continues to be thrown by the right ventricle of the heart into the lungs. But the little air contained there soon parts with its oxygen; and then the change in the blood ceases to occur, and dark blood is sent from the lungs to the heart, and thence to all the organs. These can not go on to do their duty without the stimulus of arterial blood.

The brain, therefore, gives out, and there is insensibility. The muscles cease to act, and all motion is gone. If a good supply of arterial blood could be furnished to all the organs until breathing could be again commenced, life would be preserved, and there is provision for such a supply in certain animals that can remain under water for some time.

170. Singular Provision in the Whale.—For example, in the whale there are large reservoirs for containing arterial blood, which can be used for the supply of the organs while he remains under water. When the supply begins to be exhausted, the animal of course has those uncomfortable sensations which a predominance of purple blood is so apt to produce. He manifests his uneasiness by his puffing and blowing, as he rises to the surface to get a fresh supply of air, and with it a fresh supply of arterial blood in the reservoirs.

171. Respiration in Fishes.—The apparatus of respiration varies in different animals. It appears in three forms—lungs, gills, and tracheæ or air-tubes. The gills of the fish are arranged in fringed laminæ, in order to present by all their minute divisions a large surface; and these delicate organs are covered with a lid FIG. 87. to protect them from injury. The blood-vessels, which contain the blood to be changed, branch out on the surface of the fringes of the laminæ, just as the blood-vessels in lungs branch out on the surface of the air-vesicles. The air which is to change it is mingled with the water. It acts upon the blood, as the water containing it, after being taken into the mouth of the fish, passes out through these laminae, as through a sieve. That the air in the water is the cause of the change can be proved by experiment.

If a fish be placed in a vessel with its orifice closed, so that no air can enter, it will soon die from suffocation, because the air in so small a portion of water is soon used up. Although the fish can not with his gills use air that is not mingled with water, it is supposed that it is merely because the gills soon become dry when exposed to the air, and that the air would act on the blood in the gills if they were only kept moist. Indeed, in the land-crab, that has the power of living for some time out of the water, it has been found that there is a gland in the gill-chamber which furnishes a secretion to keep the gills moist.

Gills differ much in their shape and arrangement in the various aquatic animals. In Fig. 87 is represented the arenicola or lob-worm. Here the gills are in the form of tufts arranged along the outside of the body. They take a somewhat similar form in the larvæ of many aquatic insects, as seen in Fig. 88. A large surface is presented to the air contained in the



LOB-WORM.

water by the delicate and beautifully arborescent gills of these animals.

FIG. 88.

LARVA OF THE
MAY-FLY.

172. Respiration in Insects.—In insects, we find the respiration effected by *tracheæ* or air-tubes. These go into all parts of the body, and the air contained in them acts upon the blood in the tissues of the body. The insect, therefore, has no distinct respiratory organs situated in any one part of the body, but the air is carried into every part. This seems to be necessary on account of the feeble circulation in the insect.

The tracheæ which, as Cuvier says, conduct the air in search of the blood, as the blood has no means of travelling in search of air, open on the surface by *stigmata*, as they are called, which are of various shapes and number in different insects. In the grasshopper there are twenty-four, arranged in four rows. You can suffocate an insect by simply covering the stigmata with varnish.

In Fig. 89 are represented the tracheæ in an insect, the nepa or water-scorpion. The tracheæ, as you see, send branches out in every direction, so that air is introduced into every part of the body. There are lungs, so to speak, everywhere in the insect.

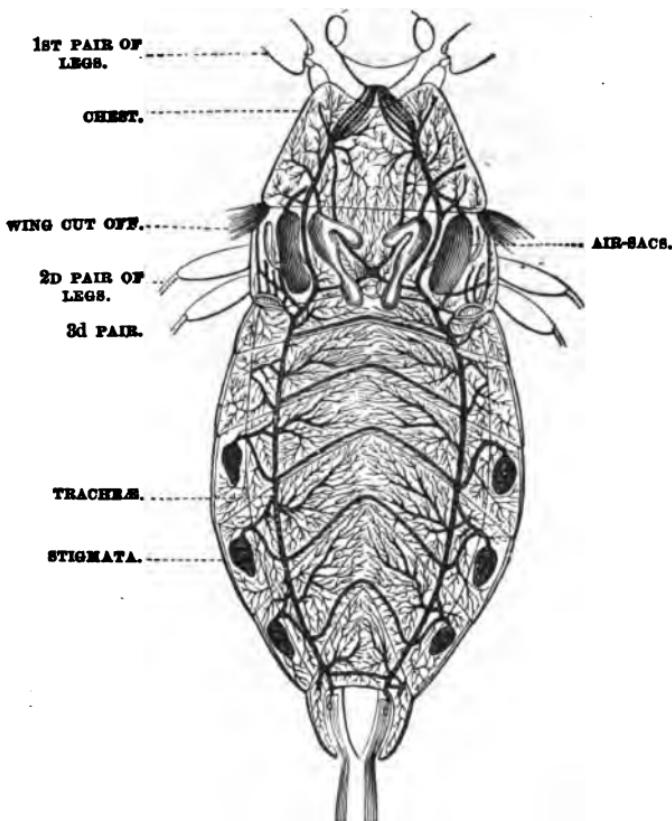
173. Respiration in Birds.—The apparatus of respiration is largely developed in birds for two objects—to provide for the extensive change in the blood which is required by their great activity, and to give lightness to the body.

To secure these objects there are air-sacs connected with the lungs, and located in different parts of the body; and in birds that fly rapidly and are long upon the wing, these sacs are very extensive, and even many of the bones are made hollow, and are connected with the air-sacs.

By this arrangement, the air is introduced extensively to the blood in the capillaries on the walls of these sacs, and at the same time the body is made very light. And the heat

generated by the effort of flying must expand the air in the air-sacs and swell them out, and thus make the body lighter. In Fig. 90 is seen this arrangement of air-sacs in the ostrich. The lungs, *l*, *l*, are quite small, but the air-sacs, *c*, *c*, *c*, are very large. The orifices by which they communicate with the lungs are as shown in the Figure. In birds of great powers of

FIG. 89

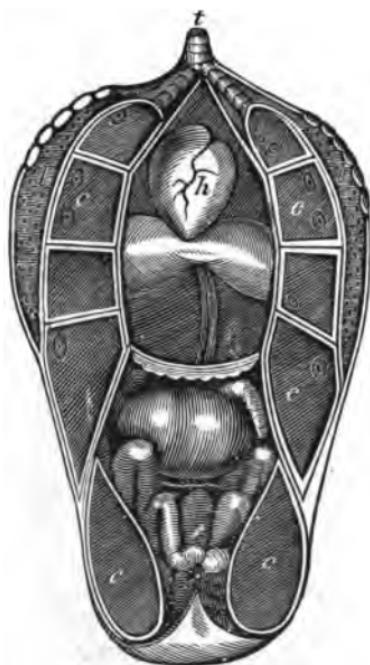


RESPIRATORY APPARATUS OF THE WATER-SCORPION.

flight, the air-sacs are much more extensive. This arrangement of air-sacs in different parts of the body of the bird bears some analogy to the tracheæ distributed in the bodies of insects.

174. Changes produced in the Air in the Lungs.—You have seen that the object of the apparatus of respiration is to change venous blood into arterial, and you have also seen how the air is introduced to the blood in order to effect this change.

FIG. 90.



LUNGS OF THE OSTRICH.

And now the interesting inquiry arises, what are the actual changes which occur, both in the blood and in the air, in the lungs. If you take a tumbler filled with lime-water, and breathe into it through a tube, the lime-water will become turbid, and will soon deposit a sediment. This is chalk, or carbonate of lime, formed by the union of the carbonic acid gas exhaled from the lungs with the lime in the lime-water. Whence comes this carbonic acid gas, and how is it formed? In order to answer this question satisfactorily,

we must learn something of the chemical constitution of the air which we breathe.

It is composed of two gases, oxygen and nitrogen. In every 100 parts of common air, there are 79 parts of nitrogen and 21 of oxygen. It is found that the oxygen is that constituent of the air which is necessary to life. If an animal be placed in a closed jar filled with common air, he will soon die, and the oxygen will be found to have disappeared, while the nitrogen will remain very nearly as at first.

If, now, one animal is placed in a jar of nitrogen, and another in a jar of oxygen, the one in the nitrogen will die immediately, while the other will be very lively until the oxygen is mostly used up by his lungs. The animal in the pure oxygen will breathe at first more rapidly than the animal in the jar of common air; and it is thought that oxygen is too stimulating for the lungs, and therefore needs to be diluted with the nitrogen, since the latter is always found in the air that we breathe.

175. Change takes place in the Capillaries.—In the case of both the animal in the jar of air, and that in the jar of oxygen, carbonic acid is found to have taken the place of the oxygen which has disappeared. This gas is made by a union of oxygen with carbon or charcoal. It was formerly supposed that this union is effected in the lungs—that carbon is thrown off from the venous blood in the lungs, and that the oxygen of the air there unites with it, and so carbonic acid appears in the air expired from the chest. But it has been discovered that the exchange is not made in the lungs. The oxygen is absorbed by the blood, and goes with it to the heart to be sent all over the system. And it is in the capillaries that the oxygen unites with carbon to form carbonic acid.

The union takes place while the blood is changing from arterial to venous, and is an essential part of the change. The carbonic acid thus formed in the capillaries, is brought back to the heart in the venous blood, and is discharged from the system in the lungs. That the change takes place as stated has been abundantly proved in various ways.

It has been found by experiments which will not be detailed, that carbonic acid exists in considerable amount in venous blood ; while, on the other hand, there is much oxygen in arterial blood. The inference from this is, that oxygen unites with the blood as it passes through the lungs, goes with it to the capillaries, and there unites with the carbon, giving us the carbonic acid which we find in the blood in the veins, after it has passed into them from the capillaries.

It has been found, also, that if frogs or other cold-blooded animals be placed in hydrogen or nitrogen (gases which produce no injurious effect on them) they will give off for some time nearly as much carbonic acid as they would have done in common air.

In this case, as no oxygen is introduced into the lungs, the carbonic acid cannot come from any union effected in these organs between carbon and oxygen, but it must be discharged by exhalation from the blood as it is passing through the lungs. Of course the discharge of the carbonic acid ceases after a little time ; for, there being no new supply of oxygen by way of the lungs, as there is when the animal is breathing common air, there can be no new formation of carbonic acid.

But even cold-blooded animals can not live in these gases for any great length of time, for oxygen is needed for the continuance of their functions. And in the warm-blooded animals, a constant supply of it is necessary—they will die if cut off from this supply even for a short time.

176. Changes produced in the Blood by the Air.—The change which takes place in the blood as it passes through the lungs, occurs to some extent when the blood is exposed to the air in any way. Thus, if blood be drawn from a vein into a bowl, the surface of it becomes red by the action of the air upon it. Carbonic acid is discharged from it, and the oxygen of the air takes its place, uniting with the blood, just as the process occurs in the lungs. A larger part of the blood will be thus changed, if it be shaken so as to expose more of it to the air. The change takes place

to some extent even if a membrane be interposed, as when the blood is inclosed in a bladder. The oxygen of the air, in this case, is introduced through the bladder, and the carbonic acid gas escapes through it. Precisely in this way is the change effected in the lungs, as already stated.

The blood is separated from the air by being confined in blood-vessels, and the air in the vesicles acts upon it through the walls of these vessels. And, as the blood is divided into innumerable little streams, every part of it is acted upon by the air in the vesicles. Though the texture of the lungs is exceedingly delicate, yet the blood is confined to its limits, even though it courses through these organs with great rapidity, and it never mingles with the air except as a consequence of actual disease.

177. Quantity of Carbonic Acid given out by the Lungs.—The quantity of carbonic acid discharged from the lungs in the course of twenty-four hours is very great. Many experiments have been tried and calculations made to ascertain its amount, from which it is estimated that there is at least three-quarters of a pound of charcoal in the carbonic acid thrown off from the lungs of a common-sized adult in the course of twenty-four hours.*

178. Necessity of Ventilation.—This gas is a deadly poison. When accumulated in a considerable amount, as when charcoal is burned in an open furnace in a close room, it may prove immediately destructive to life. And in the very prevalent neglect of ventilation, the frequent accumulation of this gas from the respiration must prove more or less injurious to the health.

Whenever the proper amount of oxygen gas is withheld from the lungs, and carbonic acid takes its place, the quality of the blood is impaired from incompleteness of the change effected in the lungs, and the vigor of the body must in this way be lessened, to say nothing of the deleterious influence of this gas upon the nervous system. Though the results

* Three-fourths of a pound of carbon united with oxygen will form two and three-fourths pounds of carbonic acid.

are not immediate and palpable, great injury is continually done to the health of multitudes by the accumulation of this gas, in small close apartments, and in crowded assemblies.

A congregation of twelve hundred people throw off from their lungs in two hours an amount of carbonic acid that contains seventy-five pounds of charcoal. And yet little pains is commonly taken to carry off this vast quantity of poisonous gas, and replace it with pure air.*

179. Carbonic Acid Exhaled from the Lungs of Animals Absorbed by Plants.—As so much oxygen is absorbed in the lungs of all animals, and so much carbonic acid is thrown out from them, the inquiry arises how the air is replenished with oxygen, and is cleared of the carbonic acid which is thus so largely mixed with it. It is found that this is accomplished, to a great extent at least, by the leaves of plants. The process which goes on in these lungs, as they may be called, of the plants, is quite the reverse of that which is going on in the lungs of animals.

The carbon of the carbonic acid which is thrown off from the lungs of animals is absorbed by the leaves of plants, and the leaves replenish the air with the oxygen, which is so constantly and abundantly absorbed in the lungs of the animal creation. Thus the animal and vegetable kingdoms are sources of supply to each other.

It may be thought that there would be a surplus of oxygen in the atmosphere in warm climates, where the vegetation is so luxuriant; while, on the other hand, there would be an accumulation of carbonic acid gas in the colder regions. This would be so, if the air were not so movable that the equilibrium is readily secured in either case.

180. Light Necessary.—It is an interesting fact, that the presence of light is necessary to the process which has been described as going on in the leaves of plants. Each leaf may be considered as a laboratory, and the light as the

* It is estimated or perhaps determined that each individual ought to have at least 800 cubic feet of space to himself, this space to be constantly supplied with pure air, with provision for the exit of the foul air, or—in other words—this space to be perfectly ventilated.

chief agent in effecting the chemical changes that occur in it. And it is found that no artificial light can do the work. It is only the light of the sun that is competent to this chemistry.

And as these innumerable laboratories are everywhere at work, absorbing the carbon and exhaling the oxygen, to purify the air rendered noxious by the laboratories of the animal creation, we must confess it to be a mystery how the chemistry of the lungs of animals and that of the leaves of plants should be kept so nicely balanced. The balance is so strictly maintained, that the chemical composition of the air is always found to be almost exactly the same.

181. Animal Heat.—The heat of the body is maintained by the union which takes place in the capillaries between the carbon and hydrogen of the system, and the oxygen which is introduced into the blood through the lungs. It is a process analogous to combustion. When carbon or charcoal is burned in a vessel containing air, the oxygen unites with the carbon, and carbonic acid gas is formed.

The same union occurs in this case between carbon and oxygen that we find occurring in the capillaries. A sort of combustion is going on in every part of our bodies. And, as heat is evolved in the one case, so it is in the other. The same can be said of the burning of *hydrogen* and oxygen together. Heat is caused by the union thus produced between them, and so it is when they unite in the body. The water which is exhaled from the lungs comes from this union of oxygen and hydrogen.

It was formerly supposed that the union between the oxygen and the carbon and hydrogen takes place in the lungs, and that the heat is made there, and then is distributed over the whole system. But it was objected to this supposition, that it made the lungs a sort of furnace for the rest of the body, and that, if the supposition were correct, there ought to be a much higher degree of heat in these organs than anywhere else, which is not the case. It was at length dis-

covered that the union between the oxygen and the carbon and hydrogen occurs in the capillaries of the body instead of the lungs; that the combustion that produces the heat occurs throughout the system, instead of in one locality.

182. Three Sources of Fuel.—The fuel for this combustion comes from three sources. One of these is the waste of the tissues. This furnishes a considerable amount of the carbon and hydrogen for the union with the oxygen, in all animals that are subjected, from their activity, to much wear and tear of the system.

Another source of the fuel for combustion is food. The oils, sugars, and starchy kinds of food are devoted in a great measure to this particular purpose. These furnish a sort of floating fuel, as we may express it, which is carried about in the blood. Hence, we see that our diet must necessarily be varied according to the weather and the climate.

In cold weather the heat of the body is more rapidly abstracted than in warm weather, and, therefore, we need then more of that food which affords a supply of carbon and hydrogen. Similarly, the enormous quantity of oily food often consumed by inhabitants of very cold climates is burned, as we may say, in the capillaries to keep up the animal heat. Of course, keeping the body warm by fire and clothing relieves from the necessity of taking any large quantities of fuel-making food. In the most favorable circumstances there is a need of variation in diet to suit the weather and the climate, and we make this variation for the most part instinctively. Indeed there is a marked provision in nature for it.

While there is a large amount of fat in the bears and seals and whales which afford food for the Esquimaux and Greenlander, there is very little in the animals which furnish a part of the diet of the inhabitants of tropical climates.

Still another source of animal heat is the store of fat which is laid up in the body. One design of this accumulation of fat in different parts of the body seems to be to provide for the heat when other sources fail. Thus, when

disease destroys the appetite, and thus cuts off the supply of food, the fat wastes away, or rather is burned up, to keep up the temperature of the body. The fat is the great means of maintaining the requisite temperature when hibernating animals become torpid for the winter. They become very fat in the autumn, before crawling into their winter quarters, and in the spring they come out very lean, their fat having been consumed in keeping up even the low degree of temperature required during this time.

183. Animal Heat differs in Cold and Warm-blooded Animals.—As the amount of heat produced, when charcoal is burned in air, or when oxygen and hydrogen are burned together, depends upon the quantities of carbon and hydrogen that unite with the oxygen, so, also, the degree of animal heat depends upon the quantities of carbon and hydrogen that unite with the oxygen in the capillaries. This may be illustrated by referring to the effects of exercise on the heat of the body.

When the circulation is quickened by exercise, the blood passes more rapidly than usual through the lungs, the respiration is consequently quickened, more air is introduced into the lungs, and therefore oxygen is more rapidly absorbed by the blood. At the same time, the action of the muscles effects a waste of their tissue, so that more carbon and hydrogen are ready to be released to be united with the increased oxygen. Hence comes the heat produced by exercise.

So, too, those animals which are the most active, ordinarily have the most animal heat, and have the most extensive respiratory apparatus, so that there may be a free supply of absorbed oxygen to unite with the carbon and hydrogen of the changing tissues. It is in birds and insects that this union takes place most largely, and in them, therefore, the respiratory apparatus is very largely developed. This is made necessary by their muscular activity, which produces so much waste matter that must be removed from the system.

Cold-blooded animals, on the other hand, are very inactive. There is not, therefore, much wear and tear of the

tissues. There is comparatively little waste, therefore, to be thrown off. And so but little oxygen needs to be introduced into the lungs, and consequently little heat is generated. To realize fully the contrast between the warm-blooded and the cold-blooded animals in these respects, observe, as the representative of the one class, a canary bird, and a frog as the representative of the other.

The frog is generally quiet, and only now and then takes a leap, or croaks; but the bird is ever in restless motion, and sings much of the time with all his might. The bird is warm with the heat generated by the constant union of oxygen with carbon and hydrogen in its capillaries; but the frog is nearly as cold as the water in which he is immersed. The bird breathes rapidly, to let the oxygen of the air largely into his lungs; but the frog seems scarcely to breathe at all, so scanty is the supply of oxygen which he needs.

184. Uniformity of Animal Heat in the Warm-blooded Animals.—Cold-blooded animals are very nearly of the same temperature with the substances that are around them; but warm-blooded animals have a certain degree of temperature, which they maintain with considerable uniformity under all variations of temperature in the atmosphere. This in man is about ninety-eight degrees Fahrenheit. This is above the temperature of the surrounding air, except in exceedingly hot weather. The human body is therefore always giving off heat.

But the amount of heat which the human body can bear for a short time is much greater than the facts above alluded to would lead us to suppose. It was long taken for granted, that it could not safely bear, even for a short time, a heat much higher than that which is endured in hot climates. The truth on this subject was at length discovered by accident.

185. Interesting Experiments.—Two Frenchmen were employed by government, in 1760, to devise some method of destroying an insect which infested the grain at that time. The result of their experiments was the dis-

covery, that by subjecting the grain to a certain degree of heat in an oven the insect was destroyed, while the grain was not injured. While they were trying their experiments, a girl offered to go into the oven and mark the height of the mercury in the thermometer. It stood at 260° ; and, after remaining there for ten minutes, which she found that she could do without any great inconvenience, she marked it at 288° , that is, 76° above the boiling point of water.

These facts led to the famous experiments of Dr. Fordyce and Sir Charles Blagden, in England. With wooden shoes, tied on with laces, they went into a room in which the thermometer showed the air to be at 260° . Their watch-chains were so hot that they could scarcely touch them, and eggs were roasted hard in twenty minutes, and beefsteak was cooked in thirty-three minutes. And yet the same air that produced these results was breathed by them with impunity, and it raised the heat of the body but very little.

The air which was breathed out from the lungs was so much cooler than the air of the room, that it was refreshingly cool to the nostrils, and to the fingers as they blew upon them. In such cases, the evil effects of the heat are prevented chiefly by the great amount of perspiration that occurs, the vaporization of this abstracting the heat, which would otherwise accumulate in the body and produce disastrous results. The exhalation from the lungs, also, has some influence.

186. Different Degrees of Torpor in Hibernating Animals.—In the state of hibernation, to which reference has several times been made, the torpidity varies in degree in different animals. In cold-blooded animals, respiration and circulation may, in this state, cease altogether. In them the movements of life are often, perhaps we may say generally, as fully suspended as they are in the seed that is kept from heat and moisture. They may be preserved in this state for a long time and yet revive.

Serpents and frogs have been kept in an ice-house for three years, and then have been revived on being brought out into a warm atmosphere. In the warm-blooded animals

that hibernate, the torpidity is less deep than in those which are cold-blooded. In them the respiration and the circulation become very slow, but never entirely cease. Indeed some species take food with them into their winter quarters, and occasionally wake up sufficiently to eat. But most of them are in a quiet, deep sleep, from which they do not arouse at all till the winter is past.

In this state, as life is nearly, sometimes quite, at a stand, there is little wear and tear, and therefore little change in the tissues, and so there is need of the introduction of but little oxygen by the respiration. Dr. M. Hall, in his experiments and observations, found that the bat, when completely torpid, consumed no oxygen, and discharged no carbonic acid from the lungs, although its circulation was not entirely suspended.

187. Relation of Activity to Quantity of Air. The more active is the respiration of animals, the less able are they to bear a deprivation of air. A warm-blooded land animal will die if it be under the water only a few minutes; but a cold-blooded animal can live under the water for some time, because it is not in so urgent need of oxygen. And, for the same reason, a warm-blooded animal, in a state of hibernation, may be kept under water for a long time without destroying life, although when in its active state it would die on being kept under water for only a few minutes.

188. General Summary.—The extensive play which the respiration has in the vital operations of the system has been shown. You have seen what the chemical changes are, which it effects directly in the lungs, and indirectly in the system. And you have seen how the animal heat is produced by these changes, and how it is so regulated, that it seldom varies from its fixed standard. But it is to be remembered that, while the lungs, and even the capillaries everywhere are thus chemical laboratories, the nervous system exerts a constant influence upon this chemistry of the body. This is especially seen in regard to the production of heat, but it is true of the whole range of the chemical operations. The

laboratories would all cease their work if their nervous connections were destroyed.

CHAPTER X.

FORMATION AND REPAIR.

189. Formative Cells appended to the Capillaries.—The building and the repairing of the various structures of the body are done by vessels appended to the capillaries. The capillaries having received from the arteries the blood, the building material, the formative vessels select from it, while it is in these capillaries, whatever they need for their purposes. Those vessels which, for example, form bone, select from the blood very different constituents from those which make nerve or muscle.

190. Concert of Action.—These builders of the body not only have the power of selecting their building materials from the blood, but they work in concert. Each company of builders work together in harmony, as if they were under intelligent leaders. And though different companies may be in close proximity, there is no disagreement nor interference. For example, the builders of a tooth and the builders of the gum around it, do not encroach on each other; but each do their appropriate work within their assigned limits. Even when different structures are intermingled, as when tendon and muscle mingle together at their place of union, there is no confusion in the work of the two sets of laborers.

191. Concert of Action shown in Producing different Shapes.—The concert of action which we observe in the different sets of formative vessels is to be looked at from another point of view. It is such that they give a definite and peculiar shape to the structure which they make. Each bone differs in shape from every other

bone, each muscle from every other muscle; and so of other parts. There is very great variety of shape in the structures of the body; and each shape can be determined only by a certain concert among the builders.

This concert of action may be looked at from still another point of view. In the growth, that is, the construction of any part, the addition is made by the formative vessels at every point of the part, and not upon the outside merely. As these builders are at work enlarging the part in the growth from infancy to childhood, they must so act in concert as to preserve the same general form in the part during all the successive stages of growth. And, as all the different structures of the body enlarge together, there must be agreement between different sets; else there would be encroachment and confusion.

192. Change of Action.—But this concert of action appears the most wonderful when a new action, or change of action, is called for. In the transition from childhood to youth, for example, the builders of the apparatus of the voice, the larynx, all at once become unusually active in their work, and a great enlargement of this musical instrument, for such it is, takes place, so that it may now utter the grave notes of manhood.

Soon, too, the beard-builders begin their new work upon the face. And during the period of childhood new operations have been continually instituted among the builders of the teeth, as one tooth after another has made its appearance, and as the new set have replaced the old.

To effect each one of these changes, there must be concert of action among the formative vessels; and there must be a most wonderful concert among the different successive sets of builders, to make all these series of operations work out at length the general result.

193. Tadpole and Frog.—This change of action in the formative vessels is strikingly exemplified in some animals. We refer to those that entirely change their forms during the period of their existence. One example will be given; the common frog. He is at first what is termed a

tadpole, and goes through many successive changes to become a complete frog. These changes are represented in the following figures. The relative sizes are not preserved, the tadpole state being represented relatively much too large, for the purpose of showing more clearly the development of the legs. The young tadpole is represented in Fig. 91. It has a large head and body, and a long flat tail by which it swims easily. There are no prominences to indicate the putting forth of any thing like limbs. It has gills, in the form of loose fringes on each side of the head.

FIG. 92.



FIG. 91.

FIG. 93.



FIG. 94.



FIG. 95.

FIG. 96.



These gills after a time disappear, and it has another set of gills arranged under a fold of skin very much like the gills of a fish. The form is then as in Fig. 92. The next change is this. The hind legs begin to grow out as seen in Fig. 93. Next, the four legs appear as seen in Fig. 94. The tail is still very large. This now gradually disappears while the legs grow as represented in Fig. 95.

In Fig. 96, representing the perfect frog, the tail has entirely disappeared. With these exterior changes interior ones have been going on also. The animal, which was at

first like a real fish, breathing with gills and swimming in water, has lost its gills, and has now a pair of lungs ; and it is no longer able to remain long under water, but must come to the surface to breathe the air.

194. Change of Action to meet new Exigencies.—The change of action in the formative vessels, which is sometimes called for by accident and disease, exhibits in an interesting manner the concert between these vessels as influenced by circumstances. When a bone is broken, these formative vessels set themselves at work to repair the injury, by forming new bone between and around the two ends of bone, which new bone we call callus.

195. Illustration from Processes of Inflammation.—Concert of action under successive changes is strikingly exhibited in the processes of inflammation. The following account of these processes is from a work published by the author, entitled "Physician and Patient." " You see a swelling. It after a while begins to soften. There is matter in it, but it is not yet very near the surface. But soon, at some point, it comes nearer and nearer to the surface, the wall of the abscess thus becoming constantly more thin, till, at length, it opens and discharges. The discharge continues till the swelling is nearly all gone, and the remainder is absorbed, and the part is restored to its natural state.

" Just look for a moment at the complicated character of this apparently simple operation. Here is quite a large deposition of substance which is to be removed ; and this is the object to be effected. Observe how it is done. The softening of the swelling is not a mere change of solid substances into a fluid, as if by decay, but it is the result of an active process, which we call suppuration. When this process is properly performed good pus is made, or as the old writers in medicine rather quaintly expressed it, *laudable* pus.

" This process of suppuration, when it is well done, does not go on here and there in the swelling, making it like a honeycomb with a multitude of little abscesses ; but there is a concert, an agreement of action by the vessels of the

part, as really as if they worked intelligently. It is this concert of action which not only makes the line of movement in the abscess, but points it towards the surface, instead of giving it some other direction, laterally or inward, upon some of the internal organs.

“Three different offices are performed by the vessels in the different quarters of the abscess. While some of these little workmen are forming the pus, there are others thinning the wall of the abscess in the direction of the surface, by absorbing or taking up the substance there; while there are others still, in the rear, and at the sides of the abscess, depositing substance, in order to make a barrier to prevent the pus from being diffused in the surrounding parts.

“When the absorbents have completed their passage for the pus through the skin, the pus is gradually discharged from its reservoir, and the ‘occupation’ of the pus-makers is soon ‘gone.’ The wall-builders also cease their work, and while the vacancy becomes filled up by contraction and deposition, the wall of defense, so carefully maintained so long as needed, is now taken up by the absorbents—workmen which seem to know just when, as well as how, to do their duty.”

196. Formation of all Parts from the Blood.

—Thus, all the solids and fluids in the body are made from the blood. Even the heart itself is made from the blood which it pumps into the aorta; for from this aorta go out small arteries, to carry blood to the walls of the heart for its growth and repair.

197. Waste.—Not only is there construction going on in every part of the system, but there is waste also. The wear and tear of the ever-moving machinery continually makes some of the particles useless, and these must in some way be removed. Let us see how this is done.

198. Two Kinds of Waste Matter.—There are two kinds of waste particles; and for the disposal of them two different plans are pursued. Some of the waste particles, though wholly useless where they are, can be rendered fit to be used again by being subjected to certain processes.

These, therefore, are not thrown out of the system, but are taken up by absorbents, and are carried where the necessary processes can be applied to them ; and then they are introduced into the blood, to make again a part of the building material.

But there are some waste particles that cannot be used again ; and these are so managed as to be got rid of at various outlets of the system. These two kinds of particles are taken up by two different sets of absorbents. The selecting power which they thus exert is as unerring as if they were possessed of intelligence.

199. Lymphatics. — The particles which can be used again are taken up by absorbents, which are termed *lymphatics*. These vessels are much like the lacteals, the absorbents in the intestines. They unite together, as they come from all parts of the body, into two trunks. One of these is the thoracic duct, which is the common duct both of the lymphatics and the lacteals (Fig. 6), and in which the chyle and the lymph, as the fluid in the lymphatics is called, are mingled together.

The other trunk, which receives the lymph from but a small part of the body, empties its contents into a large vein at the right side of the top of the chest. The largest part of the lymph, therefore, unites with the chyle, and is poured with it into the circulation, and the rest reaches the same destination by another way. It all becomes with the chyle a part of the blood. But before this it passes, like the chyle, through glands, in order to fit it to become again a part of the building-material of the body. These glands are everywhere in the track of the lymphatics. They are often enlarged from disease, and then they can be readily felt. In relation to this appropriation of waste particles, it may be truly said that man lives in part upon his own flesh.

Those waste particles which are entirely useless are taken up by the veins directly into the circulation. They then travel the rounds with the blood, and are thrown off from the system by organs fitted for that purpose. These organs

are the lungs, the skin, the liver, the kidneys, etc. Each of these excretory organs is fitted to throw off its particular part of the waste. Thus the lungs excrete a kind different from that which the skin does; and so of the rest.

200. Excretion and Secretion.—It is interesting to observe that some of the excretory organs perform other functions besides that of mere excretion.* Thus the lungs, while they excrete carbon, absorb oxygen, without which life could not go on. At the same time, too, they act as the bellows for the organ of the voice, the larynx, as you will see in the chapter on that subject. So, also, the liver, while it excretes what would be noxious if it remained in the blood, puts its excretion into such a form, that it proves, as you saw in the chapter on digestion, an auxiliary in some of the processes of the digestive organs.

201. The Skin.—The skin, while it is an extensive excreting organ, performs other important offices. It serves as a firm yet very flexible and soft covering to the body, protecting its internal parts from injury. It is highly endowed with nerves for two purposes—the one, that it may act as a sentinel to warn of danger; and the other, that it may be the seat of the sense of touch. What is very commonly spoken of as the skin, is not really the skin, but only a covering for it.

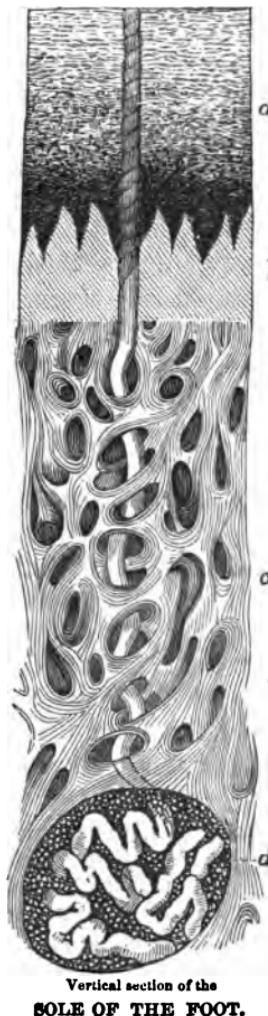
202. Cuticle.—When the skin is rubbed off, as it is expressed, it is only this covering of the skin, or *cuticle*, which is removed. The skin which is raised by a blister is this cuticle. The great object of the cuticle is to protect the true skin, which is very fully supplied with nerves for the purposes mentioned above, and which therefore, if uncovered, would prove a source of severe suffering. As it is,

* The words *excretion* and *secretion*, are often applied to the same thing. Excretion, strictly speaking, should be applied only to something to be *thrown off*, and not to something formed to be used. But sometimes an excretion is so formed that it can be used, and then the word *secretion* is also applicable to it. Thus the bile, while it is an excretion containing noxious particles to be thrown off from the system, is put to use, and so it is as often called a *secretion* as an *excretion*.

the cuticle protects the skin effectually, and yet does not interfere with its functions as the organ of the sense of touch.

It is of so slight and so soft a texture, that the nerves of touch may readily receive impressions through it. It is composed of many layers of minute round cells, the outermost layers being made up of these cells broken and emptied of the fluid which they contained.

FIG. 97.



203. True Skin.—The true skin, which the cuticle covers, is of a fibrous texture, with a good supply of both nerves and blood-vessels. On the surface of this true skin next to the cuticle are eminences called papillæ. In these are seated the extremities of the nerves of touch. Fig. 97 represents a highly magnified section of a bit of the skin from the sole of the foot; *a* is the cuticle; *c* is the true skin; *b* represents the papillæ.

204. Tubing in the Skin.—

You observe a tube which runs up through the cutis or true skin and the cuticle, and in the latter takes a spiral course. This is the discharging tube of the sweat-gland, *d*, lying within the true skin, and surrounded with globules of fat. These glands are more numerous in some parts of the skin than in others. They are particularly numerous on the palms of the hands, and on the soles of the feet.

Mr. E. Wilson counted, with the aid of the microscope, 3528 of them in a square inch on the palm of the hand. Reckoning the length of

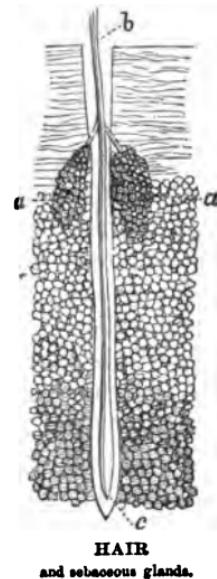
one of these at one quarter of an inch, it gives 882 inches or $73\frac{1}{4}$ feet of tubing in this small space. He calculated the amount of this tubing in the skin of the whole body as being 48,600 yards, or nearly 28 miles. The amount of excretion from the seven millions of these tubes, which open on the surface of the skin, is very great.

205. Insensible Perspiration.—The perspiration is ordinarily *insensible*, as it is termed; that is, it is in the form of vapor. But sometimes, as in vigorous exercise, when the sweat-glands are rendered very active, chiefly to prevent too great an accumulation of heat, the perspiration becomes *sensible*.

206. Sebaceous Glands.—There is another set of glands in the skin, called sebaceous glands, which secrete an oily fluid. They also have thin tubes like the sweat-glands. They are most abundant where the skin specially needs an oily lubrication, as where there are folds in the skin, or hairs, or where the skin is exposed to friction, or to the drying atmosphere. They are very abundant on the face and head. Every hair has sebaceous glands connected with it, as represented in Fig. 98; in which *b* is the hair emerging from the skin; *a a* are the sebaceous glands pouring their secretion by thin tubes into the tube or canal in which the hair grows; *c* the root of the hair surrounded with fat globules.

207. Influence of Labor on Wear and Tear, and on Absorption.—By the facts developed in this chapter, it is thus seen that there is constant change going on in all parts of the body. Particles which have become useless are taken up by the absorbents while the formative vessels deposit others to take their places. The rapidity with which this

FIG. 98.



change occurs, depends mostly upon the activity of the individual. The busy laborer, whether the labor be bodily or mental, requires more nourishment than the indolent man, because there is more waste in his case, from the wear and tear occasioned by motion or thought, and there is therefore a necessity for a larger supply of repairing material.

The difference, it is true, is not so great in regard to mental labor, as in regard to that of the body; but still it is very apparent. This dependence of the amount of change in the system upon the degree of activity is very manifest, if we compare different animals in this respect. The frog and the canary bird, in regard to respiration, have been already contrasted, and they can be contrasted in this respect also. As the frog makes but little exertion either of body or mind, there is but little change in his body, and but little nutriment is required to supply the small waste that occurs. But in the ever active canary there is much waste from this action, and therefore there must be much eating to supply the material of repair.

208. Change Varies in Different Parts of the Body, and in the same Body at Different Times.—The relation thus seen to exist between the amount of change and the degree of activity, is exemplified in a comparison between different parts of the body. In those which are most actively used the change of decay and repair is going on most constantly. The active muscles and nerves are continually changing; while the bones, which are only passive instruments of motion, are changed very slowly.

And it is a significant fact, that in the case of the muscles and nerves, the waste particles are to a large extent of the *entirely useless kind*, for they are mostly absorbed by the veins, these tissues containing but few lymphatics. That is, whenever we think, or feel, or move, we render entirely useless quantities of the particles which make up the structure of the muscular and nervous systems, and these are got rid of at the proper outlets, while other particles immediately take their places.

209. Life a Result of Death.—In this constant change going on in the body, life and death may be said to be brought into very near companionship. Every act of the mind, and every movement of the body, breaks down some of the structure; and the particles, which are no longer fitted to maintain the living functions, must be taken away as refuse dead matter, and new particles endowed with vital affinities must take their place.

Action, destruction, repair, are the successive events which are ever occurring in every part of our frame. Action is followed by destruction, and in proportion to its intensity; and repair is necessary to fit it for further action. And so through life the nutritive functions are thus struggling against the tendency to decay and death, till at length at the appointed limit the struggle is given over, the vital affinities release their hold, and the common laws of dead matter take possession of the body.

CHAPTER XI.

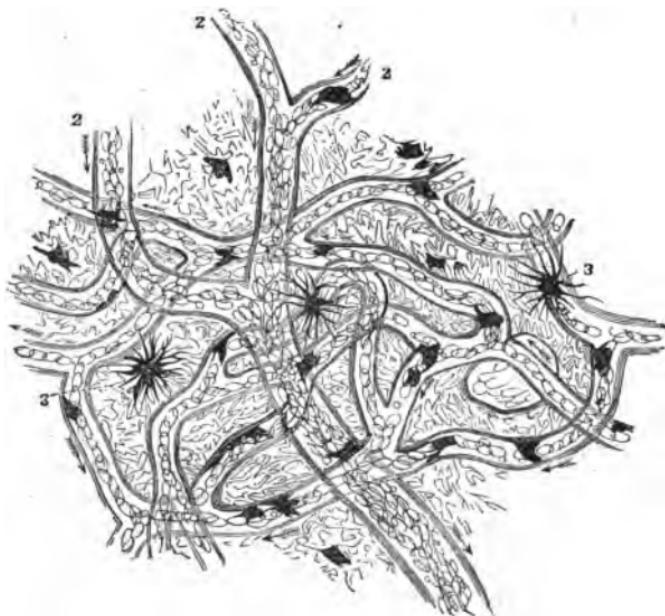
CELL-LIFE.

210. The Formative Vessels shown by the Microscope to be Cells.—It is found by the aid of the microscope, that all the minute operations of the system are performed by the agency of *cells*. They are not such cells as are found in the cellular tissue, which are mere interstices, communicating together, but they are bladders or sacs, and are filled either with a fluid alone, or with a fluid containing some grains of solid substance, termed molecules. The usual form of the cell when it first appears is globular or spheroidal. It is seldom, however, seen in this form; for, besides the change of form from the pressure of

neighboring cells, the cells themselves often assume various shapes from other causes.

211. Seen in the Blood and in most other Parts.—Cells can be seen in the blood. If the web of the foot of a live frog be placed under the microscope, they may be seen sweeping along in the blood-vessels, like so many little bladders, varying their shape, according as they press on each other, or on the sides of the vessel. This is very well represented in Fig. 99, in which a portion of the web of a frog's foot is seen as magnified 110 diameters. The dark irregular spots which you see, as at 3, 3, are pigment cells, which give the color to the part.

FIG. 99.



CAPILLARIES IN THE WEB OF A FROG'S FOOT.

Cells may be seen, not only in the blood, but also in most of the other fluids, as well as in the solids. The solid parts of animal bodies are composed either of cells, or of structures pro-

duced by cells, or of a mixture of these structures with cells. The same can be said also of plants. Cells, therefore, are the real formative vessels in both classes of organized beings.

212. Cells in the Lower Animals.—

We have very striking exhibitions of the cells in the lower orders of animals. The Hydra, a representation of which is given in Fig. 1, seems to be made up of little else than cells. If you observe under the microscope one of its arms, as it moves about, the motion appears to be a motion of the cells upon each other. There are no fibres to be seen, to which the motion can be attributed. Fig. 100 represents one of these arms highly magnified. The cells, as you see, have somewhat of a spiral arrangement.

213. Character and Color of Tissues dependent on the Contents of Cells.—

The character of many of the tissues in the body depends on the *contents* of the cells. The cell itself, or the cell-wall, as it is termed, is considered to be always the same. But the contents vary, and this variation makes generally the variation in the character, and in the color also, of the various textures.

For example, all the glands are constructed essentially on the same plan; and their difference depends upon the contents of the cells in them. Thus the liver differs from the tear-gland, chiefly because the former has cells which fill themselves from the blood with the components of bile, while the other has cells which fill themselves with the components of the tears.

The color of various parts, as the iris of the eye, the skin of the dark-colored, the hair, &c., depends upon a coloring matter which constitutes either a part or the whole of the contents of particular cells.

214. Selecting Power of the Cells.—

It is clear, from the facts which have been stated, that the cells have a selecting power. In the body they take from the common

FIG. 100.

CELLS
in the arm
of the Hydra.

pabulum or material, the blood, such constituents or substances as they need for their particular purposes. Illustrations of this have already been given, in speaking of the difference in the glands. Every cell contains its own peculiar constituents, which it has taken from the blood. For example, there are fat-cells which receive fatty matter from the blood, rejecting everything else; pigmentary cells receiving nothing but coloring matter from the blood, &c. The same thing appears too in plants. There are cells which receive from the sap volatile oil; others, fixed oil; others, starch; others, coloring matter, &c.

Fluids, and sometimes gases, enter the cells continually. The pores through which they enter are not visible even through the microscope, but of course such pores must exist. Their entrance is controlled by the selecting power to which allusion has been made.

215. Cells Real Laboratories.—Not only is there a selecting power in the cell, but there is often a converting power, by which new compounds are formed from the constituents introduced into it. The cell in this case, though so small as to be seen only by a microscope of considerable power, is a real laboratory, effecting chemical changes in its contents. There can often be seen quite a brisk movement in the molecules in the cell while these changes are going on.

216. Different Offices of Cells.—Cells, as has been already stated, do not all perform the same office, but there are cells for a great variety of purposes.

There are different kinds of cells in the blood. There are colored and colorless ones. The office of the colorless ones has not yet been satisfactorily determined. But we know more about the colored ones. These give the red color to the blood. They are not red when looked at singly, but are of a yellow cast; and the red color appears only when several are together.

217. Office of Red Cells in the Blood.—One office of these colored cells is to carry oxygen to all parts of the system, and return the carbonic acid to the lungs to be

thrown off. By carrying these cargoes back and forth in the circulation, these little cells perform a very important office. A very valuable part of the cargo of these cells is iron. In low states of the system, when the red cells are deficient, the administration of iron in some form is often found to be very effectual, in connection with a good diet, in remedying the deficiency.

The proportion of these red cells varies much in different animals. It is largest in those which are the most active. The proportion is greater generally in birds than in the mammalia, and it is much greater in the latter than in reptiles or fishes. In man it varies much in different individuals. These cells are abundant in the ruddy, strong, and active; while they are less numerous in the inactive, pale, and feeble.

218. Manner in which Absorption is Performed by Cells.—There are cells for absorption, and cells for secretion and excretion. It has been said in the chapter on Digestion, that the vessels called lacteals absorb chyle from the contents of the intestine. It was formerly supposed that they did this through their open mouths on the surface of the mucous membrane. But the absorption is accomplished by cells, which are developed for this purpose at the extremities of the lacteals. They take up the chyle and discharge it into the lacteals, and they are dissolved away in the very act of emptying themselves.

A new crop therefore of cells appears every time the process of absorption is to be performed. And, what is still more curious, every time that absorption is to take place, there is cast off, as a preparatory step, a sort of pavement of cells from over every point in the mucous membrane where there is an extremity of a lacteal. The absorbing cells are thus uncovered, so that they can perform their duty.

All this can be made clear by the following diagram. The surface of the mucous membrane of the intestine is not a perfectly smooth surface, but examined by a microscope, it is seen to be covered with eminences and depressions. Absorption takes place on the eminences, while the depressions

are the seats of secretion. In the diagram, Fig. 101, you have a representation of the arrangement of one of the eminences highly magnified. A represents it as it is in the intervals of digestion when absorption is not going on, and

FIG. 101.

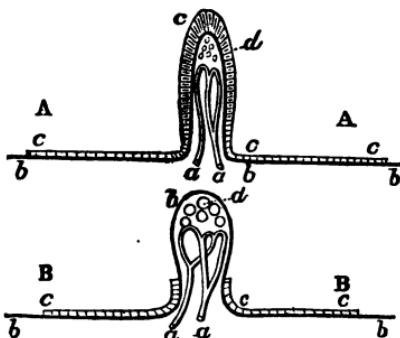


DIAGRAM SHOWING ABSORPTION IN A MUCOUS MEMBRANE.

B as it is during absorption ; *a a* are the absorbent vessels or lacteals ; *b b* basement membrane, as it is termed, an exceedingly thin membrane acting as a basement to the pavement cells *c c* ; *d d* the absorbing cells. When absorption is not going on, the prominence is somewhat shranken, and the pavement cells cover it. There are some granules or small grains, *d*, in A, which are, it is supposed, the germs of the absorbing cells, which you see developed in B. When absorption is taking place the prominence is swelled out as represented, the lacteal vessels are full, and the absorbing cells appear at their extremities, while the pavement cells have been thrown off, so that the chyle may have free access to the absorbing cells through the pores or interstices of the basement membrane.

219. Manner in which Secretion is Effected by them.—While absorption thus goes on in the eminences, secretion takes place in the depressions. The diagram, Fig. 102, represents one of these depressions, or follicles, as they are termed, in two opposite states, when secreting, and when not secreting. In A, secretion is not going

on, and the cells *e*, in the follicle, remain quiet. In *B*, on the other hand, secretion is taking place, and it is done by the casting off of cells, as represented. These cells discharge their fluid contents into the cavity of the intestine, and disappear, while other cells take their places. These

FIG. 102.

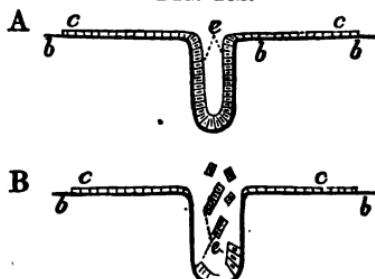
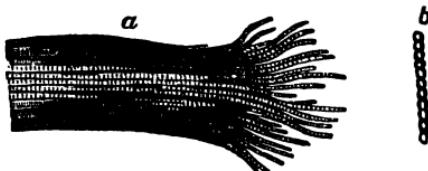


DIAGRAM SHOWING SECRETION IN A MUCOUS MEMBRANE.

follicles are really little glands. And the various glands, the salivary glands, the liver, the pancreas, &c., are made up essentially of such follicles arranged in different ways.

220. Muscles made up of Cells.—There are some cells which are devoted entirely to the production of motion, for an ordinary muscle is composed of great numbers of chains of cells included in sheaths bound together. A muscle appears to the naked eye to be made up of fibres. Each one of these fibres is found by the microscope to be composed of from 500 to 800 *fibrillæ*, or minute fibres. And

FIG. 103.

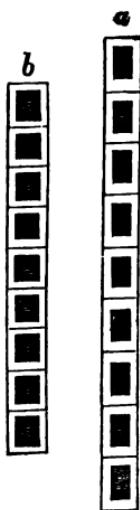


FIBRE OF A MUSCLE.

each of these fibrillæ is a series or chain of cells. In Fig. 103, *a*, is represented a fibre as seen under the microscope, showing the fibrillæ of which it is composed. They are

separated at the broken end by the violence in tearing the fibre. In *b*, you see one of the fibrillæ very highly magnified, showing that it is a chain of cells. In

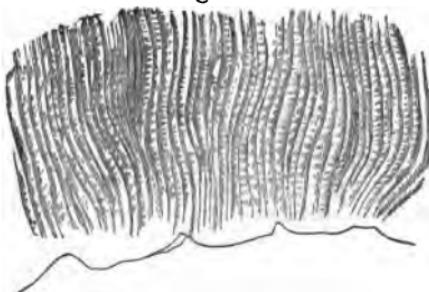
FIG. 104.

MUSCULAR FIBRIL;
a relaxed; b contracted.

is represented the condition of a fibrilla in the two states of contraction and relaxation. In *a* it is relaxed. In *b* it is contracted, the cells being shortened; and at the same time widened. And as all the cells in the muscle are thus widened when the muscle contracts, we see the cause of the well known swelling out of muscles when they are in action. That you may form some idea of the size of these cells in muscles, I will state that in the space of the square of a tenth part of an inch, thus, □, there are over 100,000 of these cells.

221. Hoofs, Horns, Nails, and Teeth made by Cells.—There are cells whose office is to make certain solid deposits. Hoofs, horns, nails, and teeth are made in this way. Even the hard enamel of the teeth is constructed by cells. They deposit it in the form of prisms of hexagonal shape as seen in Fig. 105, which represents a vertical section of enamel as seen

Fig. 105.

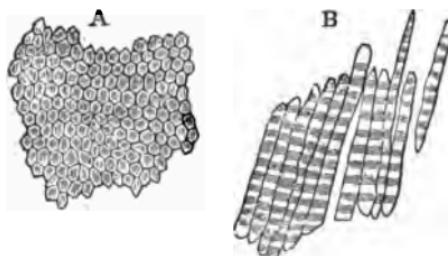


VERTICAL SECTION OF ENAMEL.

under the microscope. Their shape is more plainly seen in A, Fig. 106, which represents a transverse section of

enamel. The line of these prisms is generally wavy, but they are for the most part parallel to each other. At B are some of these prisms separated. They are more magnified here than in Fig. 105.

FIG. 106.



ENAMEL.

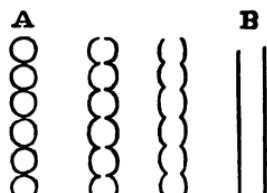
A, Transverse section. B, Separated prisms of it.

222. Nerves composed of Tubes made from Cells.—The nerves are bundles of tubes of exceeding fineness. They vary from $\frac{1}{1000}$ th to $\frac{1}{10,000}$ th of an inch in diameter. Now, each of these little tubes, or tubuli, as they are called, was once a chain of cells. The cells in each chain or row, as the microscope has shown, gradually became incorporated together to become a tube, and in this tube is contained the true nervous matter.

And it is supposed that each of these tubuli preserves itself separate and distinct, from its origin in the brain, or some other of the central organs of the nervous system, to its termination in some fibre, or on some surface. For no communications between the tubuli have ever been found by any microscopist. The manner in which these tubuli are made from cells may be illustrated by the diagram in Fig. 107, in which the steps by which the row of cells A becomes the tube B are represented.

223. All Organized Substances built up by Cells.—All animated nature is built up by cells. The first

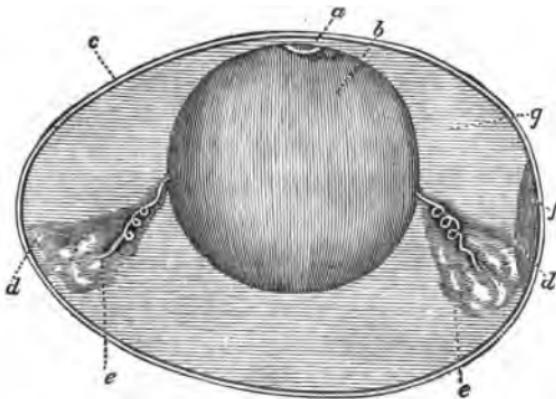
FIG. 107.



thing which comes from the supposed germ is a cell. And this single cell is the parent of all the cells which build up the whole structure, whatever it be. It is by these cells thus produced, that all plants and animals are constructed. "A globular mass," says Carpenter, "containing a large number of cells is formed before any diversity of parts shows itself; and it is by the subsequent development, from this mass, of different sets of cells, of which some are changed into cartilage, others into nerve, others into muscle, others into vessels, and so on, that the several parts of the body are ultimately formed."

224. Arrangement of the Parts of the Egg.—By an examination of different eggs at different stages of the process of hatching, the various steps in the development of the animal have been observed and noted. In the middle of the egg is the yellow yolk, composed of albumen and oil globules. It is surrounded by an exceedingly thin sac, which keeps it separate from the albumen, or *white* of the egg that envelopes it. The *yolk* *b*, Fig. 108, is lighter

FIG. 108.



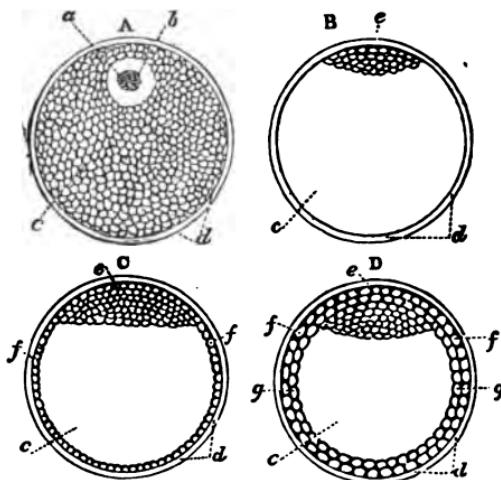
SECTION OF A BIRD'S EGG.

than the *white*, and it therefore always seeks the highest point in the egg. But it is held down by two very delicate ligaments *e*, *e*, connecting it with the white lining of the shell. And you will observe, too, that the cicatricula, or

germ-spot, *a*, which is a collection of cells beginning the process which is to form the animal, being lighter than the yolk is always at the top of it, in order to receive the warmth from the body of the bird as it sets upon its eggs. There is at the blunt end of the egg, *f*, a bubble of air which is intended as an invigorating draught for the lungs of the young bird preparatory to its bursting its shell.

225. Succession of Cells in the Yolk before the Animal is formed.—When the processes preparatory to the formation of the animal commence, the yolk itself is composed in part of cells, as represented in Fig. 109, A. In the midst of it there is a germinal spot, *a*, with a vesicle in it, *b*. This vesicle produces a cluster of cells.

FIG. 109.



DEVELOPMENT OF CELLS IN THE YOLK DURING INCUBATION.

But these cells, and those which in part compose the yolk are temporary, and all disappear. Before, however, the cluster of cells in the germinal spot disappear, there are seen in the midst of them two twin cells. These multiply; and what is singular, they do it by doubling, so that there are successively 4, 8, 16, 32, &c. At length there is a mass of them like a mulberry, as at *e*, in B. This mass then

sends off cells at its edges which makes a layer, *f*, all round the yolk as represented in C. A second layer, *g*, is formed inside of the first as seen in D. In the case of the higher animals a third layer is added.

226. Development of Organs.—There is no formation of the animal yet. Soon, however, a single large cell appears in the center of the mulberry-shaped mass of cells, and from this begins the formation of the animal. All the other parts of the egg—the cells, the yolk, the white—are tributary to the action which proceeds from this cell. Within its wall is a ring-like nucleus. This takes the shape of a pear, and then it is afterward very much like a violin. From this nucleus are produced cells which form all the various parts of the animal, the heart, lungs, stomach, brain, limbs, &c. And these are made of the yolk and the white of the egg.

From the views which have been presented in this chapter it is manifest, that *the grand distinction between organized and unorganized substances is to be found in this cell-life of the organized*. In unorganized substances particles or molecules are the only things which we know of as being concerned in their formation. But in the construction of organized substances or beings, every thing is done by the agency of cells. And in this cell-life of the living world we have another beautiful example of the divers and almost numberless results which the Creator works out by simple and single means.

As gravitation holds atoms together in masses of every size from the minutest to the largest, and keeps the mighty orbs in their appointed circuits, so cell-organization constructs and moves all living things, however small, however large, and however diversified.

227. The Power of the Deity shown in the Minute Operations of Nature.—As we examine the various workings of this cell-life, we can not but perceive the truth of the old adage, *Natura in minimis maxima est*—nature is greatest in the smallest things. The power of mere bulk or mere force we can comprehend by

mental addition, however great that power may be. We can imagine a power which we see, to be indefinitely multiplied, and thus can form the idea of immense power. But when with the microscope we see minute cells working out such results as we have contemplated in this chapter, and inquire how it is done, we see that there is a hidden power here that utterly defies our conception. The mechanics and the chemistry of the cell, who can understand them?

From the inscrutable movements of this hidden power, at work wherever life is, in the cells, its laboratories, we get a higher idea of Omnipotence than we can get from the grandest and most terrific exhibitions of mere force. We get from them the idea of an all-pervading, as well as an all-wise power, working not merely in every locality, but at every point of the universe. And the revelations which the microscope makes to us seem to draw us very near to the Infinite. As we gaze with wonder and delight at the secret operations of his power thus opened to us, we seem almost to be admitted to his presence; and even our awakened curiosity, amid the wonders now brought into our field of vision, does not suffice to remove the awe which almost oppresses us.

How great is the inner beauty of the living world around us! We admire the symmetrical forms, and the beautiful colors which nature presents to us in such variety; but there is an inner world of beauties throughout nature, still more perfect and resplendent, which is hidden from the naked eye of man, though it is all open to the Omniscient.

If you would get some idea of the beauty of this inner world, take the most delicately beautiful of all the specimens of man's workmanship, and examine it with a microscope; and then compare it with some living texture or coloring. Compare in this way, for example, the most perfect painting of a flower with the flower itself. The painting loses all its beauty as it is magnified; but in the bosom of the flower the microscope develops to you beauties far transcending those which are seen by the unassisted eye. Even such living structures as are unattractive to the naked eye, present

under the microscope wonderful beauty in the delicate lines of their textures.

It is true of every one who has used this instrument in his observation of nature, that he is impressed with the fact that, great as is the beauty of nature, as we look out upon it, it is vastly inferior both in kind and in amount to that inner beauty seen so completely by the all-seeing Eye, and now developed to us in part by the skill and ingenuity of man. And it suggests to us the hope, that in a new state of being, and with higher faculties, we shall be able to look farther into these inner beauties of the universe, than we now can with all the aids which our ingenuity can devise.*

CHAPTER XII.

THE NERVOUS SYSTEM.

228. Process of Nutrition in Plants and Animals quite alike.—Thus far we have contemplated man merely as a structure. We have observed the means by which the body is built and is kept in repair. We have seen that the functions of nutrition in man and all animals have much in common with those of plants. So far as these functions are concerned, they vary from plants only in the modes by which the nutrition is effected.

The absorbents in the root of the plant do for the plant what the lacteals in the digestive organs do for the animal, the difference between them being only according to the differing circumstances. So also, circulation and formation are in all essential points the same in these two different departments of animated nature.

* I could not find it in my heart to cut out the above paragraphs relating to the power of the Deity shown in the minute operations of nature; though they contain little of direct instruction, the reading of them can not fail to make a good impression.—ED.

229. The Nervous System — the Essential Difference between Plants and Animals.—The functions which have been treated in the previous chapters, as being common to plants and animals, are called the functions of *organic* life, because they concern merely the structure, the *organization*. But there are other functions. The body, with all its complicated parts, is constructed and kept in repair for certain *uses*.

These *uses* are secured by the nervous system,—a system which is superadded to what the animal has in common with the plant, and which, therefore, constitutes the essential difference between the animal and the plant. This system furnishes the means of the *relations* of the animal to the world around him.

He receives his impressions from external things through this system; and through it he acts upon external things. He feels through the nerves, and by the nerves excites those motions by which he acts on both material and immaterial existences.

The functions, therefore, which are performed through this system, are called functions of *animal* life, in distinction from the functions of *organic* life, which are common to vegetables and animals. They are sometimes also called functions of relation, in view of the relations which it establishes between sentient and moving beings, and all external things.

230. The Nervous System and its Subordinate Instruments.—The nerves do not themselves move, but they excite motion in muscles, and these move bones and other parts. Neither is sensation performed by the nerves alone. The different senses, for example, have different organs, with arrangements differing according to the kind of sensation. Mere nerves alone do not see, or hear, or taste, or smell, or touch.

There are special organs constructed for these purposes; and through these, the nerves receive impressions. Thus the nerve of sight can not of itself see; but the eye being there, so formed as to have pictured on a membrane the images of

objects, the nerve receives an impression from these images, and this impression is transmitted through the trunk of the nerve to the brain, where the mind takes cognizance of it; and this constitutes seeing.

231. The Higher the Rank the more Complicated the Nervous System.—The nervous system in the lower orders of animals is very simple, and forms an exceedingly small part of the animal. But, as we rise in the scale, we find that, as the limits of relation to external things enlarge, this system becomes more prominent; till, in man, in whom these relations, both mental and physical, are much more extensive than in any other animal, it is very prominent and greatly complicated.

232. All Knowledge Acquired and Communicated by Nerves.—A child as it first opens its eyes upon this world, knows nothing at the outset of shapes, or colors, or distances, or any other relations of things. This is all to be learned through the nerves and their subordinate organs. And as all knowledge is acquired through the nerves, so it is communicated through nerves to others.

It is communicated by the motions that are excited in the muscles by the nerves; by the motions of the countenance varying its expression; by the motions of the limbs, or gestures; but especially by the motions which produce and articulate the voice. *Thought and feeling can be communicated in no other way than by muscular motion.*

233. Parts of the Nervous System.—The nervous system may be considered as having three parts: 1, certain central parts, as the brain and spinal marrow; 2, nervous trunks, which going from these central parts divide and subdivide, as the arteries do, till they become exceedingly minute; and 3, the nervous expansion in the organs, having a relation to the nervous trunks similar to that which the capillaries bear to the arteries.

In what we call sensation we suppose that an impression is produced in the nervous expansion, that the trunk serves to transmit it, and that through the nervous center, the brain, it is communicated to the mind.

234. Conditions Necessary to Sensation and Motion.—Let us see now what is necessary to this compound act, termed sensation. First, it is necessary that the organ where the nerve is expanded be in a condition to let the nerve receive the impression. If the eye be so injured in its textures that the impression can not be made on the nerve, there can be no vision.

It is necessary, also, that the trunk of the nerve be in a proper condition. If the nerve of vision be pressed upon by a tumor, there will be no impression transmitted from the images formed in the eye. So, too, if a nerve going to any part of the body be cut off, there can be no transmission of impressions to the brain from that part.

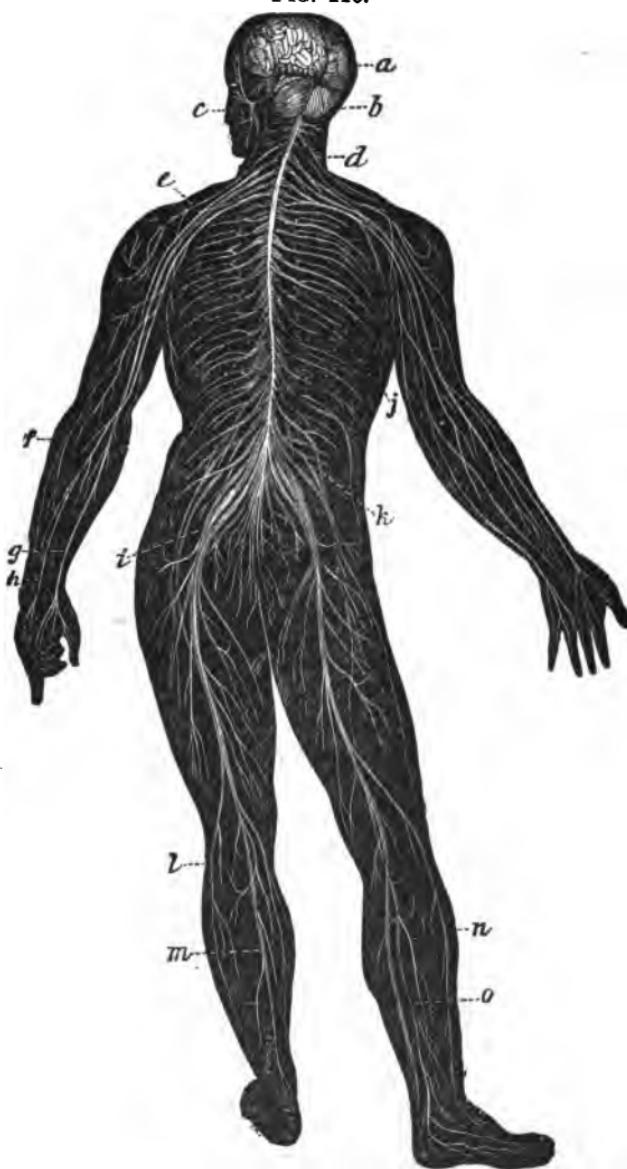
Again, it is necessary to sensation that the brain should be in a state to communicate the impression to the mind. If the brain be pressed upon strongly by a depression of the skull from violence, or by effusion of blood by the rupture of an artery, as sometimes occurs in apoplexy, there can be no sensation.

Excitement of mind, too, sometimes prevents the occurrence of sensation, by its action upon the connection between the mind and the brain. The pain of a wound received in battle is often unfelt, until the excitement of the battle is over. The aching of a tooth is often stopped by the excitement consequent upon going to the dentist to have it extracted.

In these cases the cause of the pain is acting all the while upon the nervous extremity, and the trunk of the nerve is capable of transmitting the impression, but the state of the mind is such, and such is the consequent condition of the brain, that the sensation does not occur—one link in the necessary chain is defective. The same can be said as regards the necessity of each of these links of the chain, in relation to voluntary motion, as well as to sensation.

235. General Plan of the Nervous System.—In Fig. 110 there is presented a general view of this system,—the central organs with the nerves going out from them. At *a* is the cerebrum, the upper large brain, filling up a con-

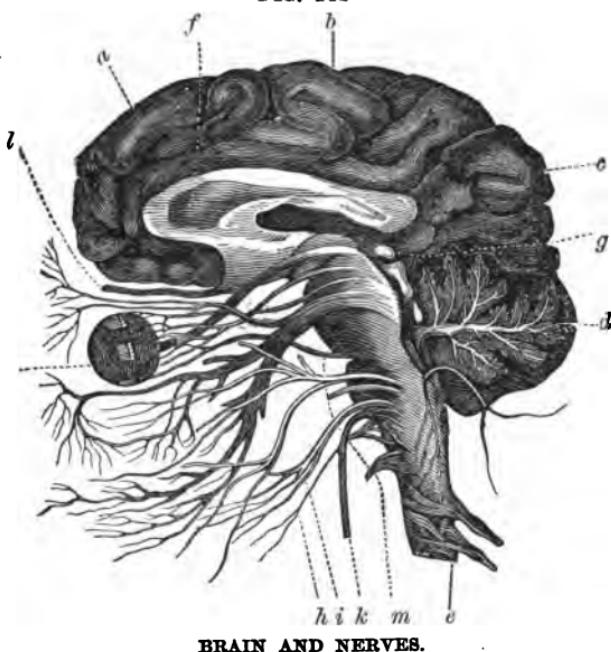
FIG. 110.



NERVOUS TRUNKS IN A MAN.

siderable portion of the skull; at *b* is the cerebellum, the smaller brain, lying beneath the cerebrum at its back part: at *c* is the great facial nerve, the chief nerve of the face; the spinal marrow, *d*, sends off branches on either side in its whole length; at *e* is the brachial plexus, a bundle of nerves coming from the spinal marrow, which here unite together, and are then distributed to all parts of the arm; at *i* is a similar plexus from which are distributed nerves to the lower extremity; *f*, *g*, and *h* point to different nerves in the arm, and *l*, *m*, *n*, and *o* to different nerves in the leg. You observe that the whole of this nervous system is divided into exactly similar halves. The cerebrum and the cerebellum are both double organs, and the nerves of one side are just like those of the other.

FIG. 111



BRAIN AND NERVES.

236. Hemispheres and Lobes of the Brain.—Having thus noticed the general arrangement of the nervous system, observe next the arrangement and structure of the brain which are seen in Fig. 111. This Figure presents to

view a perpendicular section of the brain, as made from front to rear, dividing it into two halves. You have here a view of the inner surface of one hemisphere, as it is termed, of the cerebrum, the large upper brain, which is commonly described as having three lobes or divisions: *a*, the anterior; *b*, the middle; and *c*, the posterior. At *f* is the broad band of white fibrous matter, which unites the two halves or hemispheres, of course divided in the section; at *d* is the cerebellum, showing a peculiar arrangement, called the *arbor vitae*, or tree of life; at *g* is the beginning of the optic nerve which goes to the eye; *l* is the olfactory nerve; *e* is the commencement of the spinal marrow.

237. Distribution of Nerves.—The many nerves which you see, are distributed to various parts of the face; the nerve at *h* goes to the tongue; at *i*, to the throat; and at *m*, to one of the muscles of the eye. From the beginning of the spinal marrow go forth many nerves, one of which, *k*, is a very important one, as it sends off branches to the lungs, the heart, and the stomach. It is this part of the nervous system, the top of the spinal cord, that is most immediately essential to the continuance of life. For it is through their nervous connections with the top of the spinal marrow, that the heart and lungs continue to perform their duty.

238. Functions of Respiration and Circulation depend on the Spinal Cord.—It has been ascertained, by experiments upon animals, that the cerebrum, and even the cerebellum, may be destroyed, and yet the animal will continue to breathe, and the circulation will go on for some time. But the moment that this part of the spinal cord is destroyed, from which the heart and lungs are supplied with nerves, the breathing and the circulation stop and the animal dies. So, too, in apoplexy, if the effusion of blood take place at the top of the spinal marrow, death will occur, and in much shorter time, than if the effusion take place in the cerebrum or cerebellum.

239. Cerebrum.—You observe that the cerebrum has deep irregular furrows on its surface, and that it pre-

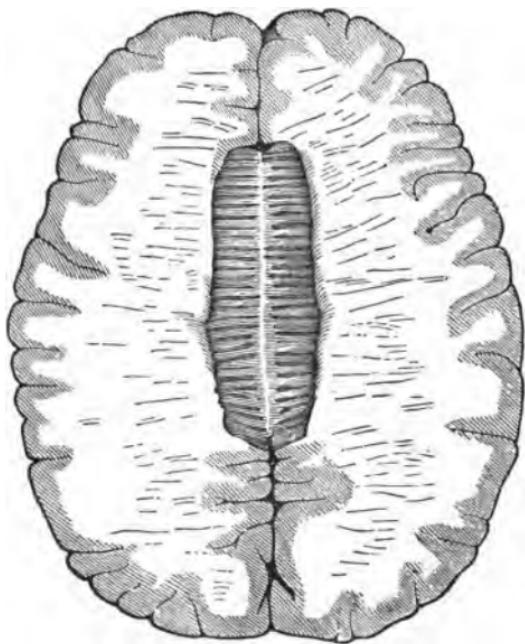
sents undulating tortuous projections. These are called the *convolutions* of the brain. Into the furrows between them dips down the membrane, in which branch out the arteries that supply the brain with blood, and the veins that return it from this organ.

This membrane is, from its soft and delicate texture, called the *pia mater* (soft mother), while the stout fibrous membrane which lies outside of this next to the bony covering is called the *dura mater* (or hard mother). The names are entirely inappropriate, for the latter serves as a protection to the brain, and the former is merely a vehicle or medium for the entrance of the blood-vessels into the brain. There is another membrane lying between these which is called the *arachnoid* membrane, because in its tenuity and delicacy it resembles the spider's web. It is one of the serous membranes, and it serves as a protecting envelope to the brain, and at the same time, by its serum, keeps this organ bedewed with moisture over its whole surface.

240. Gray and White Substances.—The substance of which the brain is composed is very soft, something like blanc-mange. It is the softest organ in the body. In color it is not uniform throughout. All around the white inner part of the brain there is a thick layer of gray substance. In Fig. 112 you have a horizontal section of the brain, showing the proportions and arrangement of the gray and the white substances. As the gray substance dips down, as you see in the figure, into all the furrows, its extent is greater than would at first view be supposed. In the middle is represented the broad band connecting the two hemispheres of the brain. You observe in Fig. 111 and Fig. 112, that there is no apparent arrangement of the external parts of the brain which would give countenance to the idea of the phrenologist in relation to its division into particular organs. The convolutions, far from presenting any well-defined arrangement, are exceedingly irregular.

241. The Gray Substance made of Cells; the White, of Tubes.—The gray substance, which is

FIG. 112.



SECTION OF THE BRAIN.

sometimes called the cortical (bark-like) substance, because it surrounds the white central part of the brain, is made up of cells, while the white part is composed of exceedingly minute tubes. These tubes are continued into the nerves, and as they hold the nervous matter, they constitute the medium of communication between the brain and all parts of the body.

This function of communication is the sole function of the white nervous matter. In the brain this white matter is a mere collection of tubes, and these branching out in bundles form the nerves. These tubes are supposed to be entirely separate from each other, from their beginning in the brain to their termination in the various parts of the body, for the microscope has never discovered any union between them at any point.

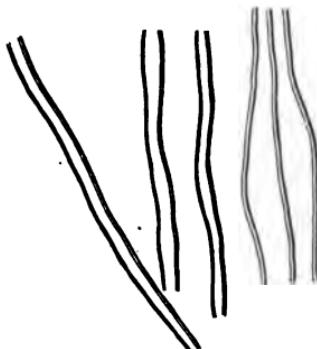
The brain, then, is a great central organ of communication, where innumerable minute tubes are brought together, each of which is connected with some one moving fibre, or some one sensitive point in the body. Those which are connected with muscular fibres transmit impressions *from* the brain, and those which are connected with sensitive points transmit impressions *to* it. Of the size of these tubes you can judge by Fig. 113, which shows some of them as they appear magnified 350 diameters.

242. Office of the Gray Matter.—The office of the gray substance, it is quite well ascertained, is very different from that of the white substance, as the difference in its structure would lead us to suppose. It is more intimately connected with the mental operations than the white substance. When, for example, motion is produced in obedience to the will, the impression producing the motion is transmitted through the white matter, but the cause of this impression does not act directly on this matter. The impression is caused by the action of the mind on the gray matter, and the white substance serves only to transmit it.

The gray matter, therefore, has a more active agency than the white in the production of the phenomena of the mind and the nervous system. It is the first link in the chain of connection between the spiritual and the physical in our nature. Hence, in examining the brains of animals, we find that the higher the intelligence is, the more abundant is the gray substance; and it is especially abundant in man, in consequence of the large development of the convolutions.

243. The Gray Substance well supplied with Arterial Blood.—A due supply of arterial blood is absolutely essential to the vigorous performance of the functions

FIG. 113.



NERVOUS TUBULI,
Magnified 350 diameters.

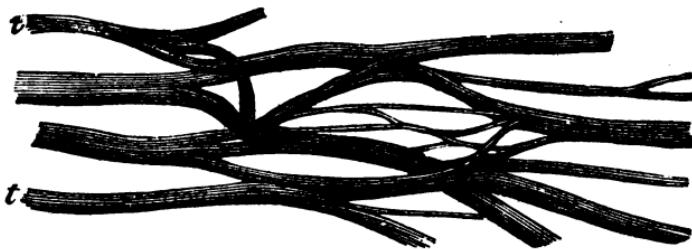
of the gray substance. If the supply be cut off in any way, as by the failure of the heart's action in fainting, insensibility and loss of the power of motion are the consequence. While the gray substance is on the outside of the brain, it is on the inside of the spinal marrow.

244. Ganglions and Plexuses.—It is also on the inside of the little bodies called *ganglions*, scattered here and there, as depositaries of nervous force—little brains, as we may term them. These ganglions are not merely a part of the apparatus of communication, as are the plexuses, which are mere combinations of nervous trunks, as seen in Fig. 115, *t t* being the trunks, which, after uniting with each other in various ways, again separate to go to their different destinations.

FIG. 114.



FIG. 115.



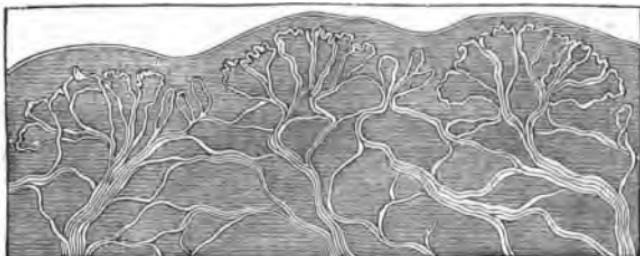
At *g*, in Fig. 114, is a ganglion into which the fibres, *f*, of the nerve, *n*, run. They then separate again into branches *b*. These ganglions *produce* nervous force, and therefore are composed like the brain in part of gray substance. The spinal marrow, too, produces as well as transmits, and so this substance forms a part of it.

245. Changes in the Nerve Cells.—This gray substance, as it is in constant operation, is subject to much

wear and tear, as we may express it, and therefore the changes of repair are constantly going on in its structure. Hence the necessity for so large a supply of blood as is secured by the network of vessels, among which the cells peculiar to this substance are scattered.

246. Termination of the Nervous Fibres.—The extremities of the fibres, or rather of the tubuli, (Fig. 113) of the nerves terminate variously. The most common termination is in loops, as seen in Fig. 116, which represents the termination of the nerves as seen through the microscope in a thin perpendicular section of the skin of

FIG. 116.



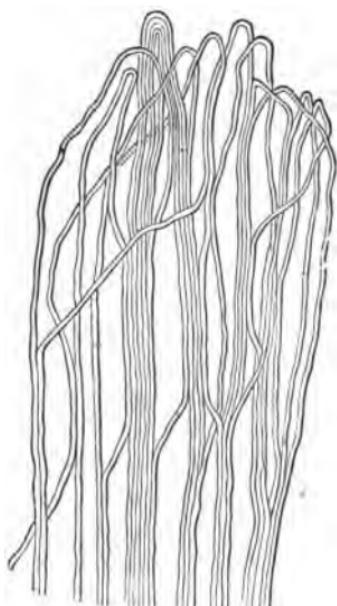
NERVES OF TOUCH IN THE SKIN OF THE THUMB.

the thumb. The three eminences in this figure are those of the *papillæ*, as they are termed, which you can see, if you look at the ball of the thumb, are arranged in curvilinear rows. In Fig. 117 you see this same loop-like arrangement of the nervous tubuli, as seen through the microscope, on the sensitive sac that lines the cavity of a tooth, the entrance for the nerves and blood-vessels of this sac being at the end of the root.

247. Pacinian Corpuscles, their Office not known.—One very singular termination of the nervous tubuli, is in what are called Pacinian corpuscles, after Pacini, the first microscopist that discovered them. They are found attached to the nerves in the hand and foot more often than any where else. Their structure, which is seen highly magnified in Fig. 118, A, is very curious. They are

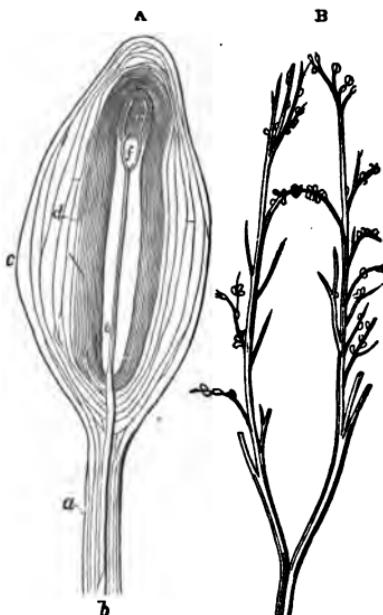
attached to the branches of the nerves, on which they cluster by little peduncles or stalks. At *a* is the peduncle; *b* is

FIG. 117.



NERVES IN A TOOTH.

FIG. 118.



PACINIAN CORPUSCLES.

the nervous fibre or tubulus; *f* is its termination in the corpuscle. In B is represented a portion of a nerve of a finger, with clusters of these corpuscles of about the natural size. Of what use these singular bodies are we know not. It has been supposed by some that they are minute electrical batteries, because they bear some resemblance to the electrical organs found in some fishes.

248. Healing of Nerves.—There is a wonderful fact in regard to the healing of wounded nerves which must not pass unnoticed. You know that if a nerve be divided, no impressions can be transmitted through it to and from the brain. But the two cut ends of the nerves can grow together, and the communication can thus be more or less restored. Sometimes it is perfect as before. Now, if you

call to mind the structure of a nervous trunk, you will see that this is passing wonderful. It is made up, you will recollect, of tubuli which are entirely separate from each other, and each one of these goes, from its origin in the nervous center to its destination, by itself. It is difficult to conceive, therefore, how the nerve can be healed without creating confusion.

249. Nice Fitting of the Tubuli.—For to avoid this, it would seem to be necessary that each little tube at its cut end must unite with its corresponding end, and not with the end of some tube with which it has no relation. For example, if the nerve distributed to the hand were cut, it would not do, as it seems to us, to have tubuli which go to the thumb unite with those which go to a finger.

And besides, as it will soon be shown you that the tubuli, through which the impression that produces motion is transmitted, are separate from those which transmit the impression that causes sensation, it would not do for a tubulus of one kind to unite in the healing with one of the other kind.

That there is, however, a very accurate union effected, is manifest from the observations of M. Brown Séguard. He examined in animals nerves which were divided twelve months before, and could not discover the point of division even with the aid of the microscope. If the tubuli were not all made perfectly continuous as before the nerve was divided, the microscope would have revealed the defect.

But it takes time to effect this adjustment of the tubuli, for it was found by Dr. Haighton that after dividing nerves, their functions were not restored till some time after they were apparently healed.

250. New Nervous Connections Formed.—Taking this view of this interesting point, the difficulty is greatly enhanced, when we look at the union of parts that did not originally belong together, as, for example, when a piece of skin is dissected from the forehead, and is twisted down so as to be made to grow on to the nose to supply a

deficiency there. Here entirely new relations are established between the nerves of the divided parts, and, as we should expect, there is confusion in the sensations. The patient, at first, whenever the new part of his nose is touched, refers the sensation to the forehead. But this confusion of the sensations is after awhile removed. And it is curious to observe, that while the old nervous connections are breaking up, and the new ones are becoming established, there is an interval of partial, sometimes entire, insensibility in the part. How these new relations can be established consistently with the known arrangement of the tubuli in the nerves is a mystery.

251. Nerves of the Spinal Marrow Compound.—The nerves through which the mind sends its messages to the muscles, are not the same as those through which it receives impressions in sensation. In and about the face, the nerves of motion and sensation are, for the most part, entirely separate from each other. But in other parts of the body, the fibres or tubuli for motion and sensation are mingled together in the same nervous trunk, inclosed in one sheath.

It is found that each of the nerves, coming out from each side of the spinal marrow, has two roots, which unite,

FIG. 119.

SPINAL CORD.
 and are inclosed in one sheath. This arrangement is represented in Fig. 119, in which *a* is a portion of the spinal cord; *d* the anterior root; *b* the posterior root; *c* the trunk formed by the union of these two roots; and *f* a branch of the nerve. At *c*, on the posterior root is one of the ganglions, or little brains, previously mentioned. Why they are placed on these posterior roots, and not on the anterior, or why they are placed here at all, we know not.

252. Different Nerves for Different Offices.—It has been ascertained by many experiments on animals, that the posterior roots are composed of tubuli, which bring impressions to the spinal marrow; while the anterior are

composed of tubuli which carry impressions *from* the spinal marrow. For, if the spinal cord of an animal be laid bare, and a posterior root be irritated, pain is produced; but if an anterior root be irritated, violent motions are caused in the parts to which the nerve is distributed. That is, the posterior root is a nerve of sensation, and the anterior a nerve of motion. It is a matter of convenience that they unite and are mingled together in the same sheath, for they are to be distributed in the same parts. In and about the face the nerves of motion and sensation are kept for the most part separate, as before stated, merely because it would be no convenience in any case to put them together in one sheath.

253. Nerves of Special Sensation.—But not only are there different nerves for sensation and for motion, but there are also different nerves for different kinds of sensation. Thus, in the eye, the optic nerve which transmits the impressions from the images formed on the retina, as will be shown in the Chapter on the Eye, is wholly separate from the nerve by which any pain or irritation is felt in this organ. The latter is called a nerve of *common* sensation—the former a nerve of *special* sensation. So in the nose, the nerve that takes cognizance of odors is a different one from that by which irritation of the lining membrane is felt. The snuff-taker smells the snuff with one nerve, and feels tingling with another.

Each set of nerves is fitted for its own peculiar office, and has for this its own peculiar susceptibility. Thus, the nerves of touch are insensible to light, and, on the other hand, the nerves of vision are insensible to touch. If, therefore, the nerve of vision be paralyzed, but the nerve of common sensation in the eye be unimpaired, although there is no seeing, the eye is as sensible to irritation as ever.

On the other hand, if the nerve of vision be unimpaired, and the nerve of common sensation be paralyzed, as sometimes happens, the individual can see, but he has lost the sentinel that stands guard over the eye, and by its warning of pain keeps it from injury. What, therefore, is flying in

the atmosphere may lodge in the eye, and though it produce no pain, it will excite inflammation by irritating the capillaries.

When the nerve of common sensation is in a healthy state, the moment any thing gets into the eye great pain is produced, and the tears flow and the eyelids are in constant motion ; and by these instinctive means, as we may term them, the irritating substance is removed. But when this nerve is paralyzed, although the irritating substance produces no pain, it gradually causes inflammation in the delicate vascular texture of the eye.

254. Different Degrees of Sensibility in the Various Parts of the Body.—Different parts of the body are endowed with different degrees of sensibility, according to their necessities, in relation to the warning of danger. Thus the skin is the most sensitive part or organ of the body, that it may warn at once of the approach of danger ; while the internal parts have much less sensibility, and some of them have none. In the performance of operations, therefore, the great suffering is in the cutting of the skin. There is very little sensibility in the muscles, and there is none in the bones.

The following fact illustrates the use of the sensibility of the skin in the prevention of injury. A man who had lost all sensibility in his right hand, but retained the power of motion, lifted the cover of a pan when it was burning hot. Although he was not aware of any effect at the moment, the consequence was the loss of the skin of the fingers and of the palm of the hand, laying bare the muscles and tendons.

255. Inflamed Parts very Sensitive.—Although there is so little sensibility in the internal parts in their healthy condition, yet when they become inflamed they become painful, sometimes acutely so. Thus, an inflamed bone is the seat of severe pain ; and the tendons, although nearly insensible ordinarily, become very painful when inflamed, as any one that has a deep-seated felon can testify. The question as to the cause of this change of

sensibility we will not stop to discuss, but that there is a benevolent object in it is very manifest. If inflammation caused no pain in such parts, it might go on to a destructive extent without the person's being aware of the danger, and therefore without his applying for medical aid.

256. Nerves not Sensitive.—It was formerly supposed that a nerve must of course have an exquisite sensibility. But there is no sensibility in nerves devoted to motion. Neither is there any in the brain itself. Portions of it can be cut off without producing any pain. The heart, too, is insensible to the touch. A case proving this fell under the observation of Harvey, the discoverer of the circulation of the blood. This absence of sensibility in the heart is not because it is not well endowed with nerves. It is well endowed, but with nerves which are devoted to another purpose. They are nerves of sympathy, which establish a connection with every part of the body, making this organ to be so easily affected by motion, by disease, and by every passing emotion of the mind.

257. Respiratory Nerve of the Face.—In the face we have an example of different sets of nerves for different classes of motions. All those motions that are used in the expressions of the countenance are associated by a certain nerve. Sometimes this nerve of expression is paralyzed on one side. The result is, that while the individual can masticate equally well on both sides, he can laugh, and cry, and frown, only on one side, and he can not close the eye on the side affected.

258. Paralysis of the Respiratory Nerve of the Face.—In Fig. 120 is a representation of this condition of things. The left eye cannot be closed by any effort, and the left side of the face is wholly devoid of expression. This nerve of expression is often paralyzed by itself, the other nerves in the neighborhood, both of sensation and of motion, being entirely unaffected. This has been called the *respiratory* nerve of the face, because it controls motions which are connected with the movements of respiration. If you observe how the various passions and

emotions are expressed, you will see that there is a natural association between the muscles of the face and those of the

FIG. 120.



PARALYSIS OF THE NERVE OF EXPRESSION
on one side of the face.

chest in this expression. This is very obvious in laughing and in weeping. When the nerve of expression, or facial respiratory nerve, is paralyzed, all the motions of the face connected with the respiration are absent.

Though the individual may sob in weeping, or send forth the rapid exhalations of laughter, yet the face on the side where the nerve is paralyzed will be perfectly quiescent. So, too, those movements of the nostrils which are sometimes used in expression, are rendered impossible.

Sneezing and sniffing up can not be done on the affected side. Neither can the individual whistle, because a branch of this nerve goes to the muscles at the corner of the mouth.

259. Nerves of the Eye.—The eye has six different nerves, each having its distinct office and its separate origin in the brain for a different service. 1. The optic nerve, whose sole office is to transmit impressions from the images formed in the eye to the brain. 2. A nerve of *common* sensation, through which any irritation in the eye is felt. 3. A nerve which is distributed to the *muscles* of the eye generally, and to no other parts of this organ. 4. A nerve which goes only to one of the oblique muscles of the eye. This is an involuntary muscle which performs the insensible rolling motions of the eyeball, and is associated with the muscles of expression in the countenance by means of nervous connections. 5. A nerve which goes to another single muscle, which turns the eye outward. 6. A branch of the respiratory nerve, which regulates the motion of the eyelids, and has much to do, therefore, with the expressions of the countenance.

260. Paralysis affecting Different Nerves.—Attention has been incidentally called to the fact, that one nerve may be paralyzed, while others distributed to the same parts are entirely unaffected. So, too, in the nerves which go out from the spinal marrow, composed of tubuli of motion and sensation mingled together, one set of the tubuli may be affected while the other is not; for in paralysis it is often the case that sensibility remains while the power of motion is gone, and *vice versa*.

Sir Charles Bell relates an interesting case, in which the paralysis was different in the two sides of the body. A mother was seized with a paralysis, in consequence of which there was a loss of muscular power on one side, and a loss of sensibility on the other. She could hold her child with the arm of the side which retained its power of motion but had lost its sensibility, but only when she was looking

at it. She could not *feel* her child on the arm, and therefore when her attention was drawn to any thing else, and she ceased to have her eyes fixed on the child, the muscles having no overseer, as we may say, to keep them at work, were relaxed at once, and the child would fall from her arm.

261. Nerves, though having Different Offices, all alike in Structure.—The microscope shows us that the nerves of motion and of common and special sensation are all alike in their structure, and chemistry shows us that they are alike also in their composition. The question arises, then, why the impression producing motion can not be transmitted by the same nerve with the impression causing sensation. The reason is evidently not to be found in the nervous trunk itself, as this is the same in all cases.

It is in the circumstances of the two *ends* of the nerve—that which is in the nervous center whence it arises, and that which is expanded in some part of the body. The nervous tubuli which end in the fibres of a muscle can not transmit impression to the brain from the skin over the muscle, because they do not go to the skin at all. There are other tubuli that are distributed there for that purpose, mingled indeed in most cases with the tubuli for motion, but yet kept entirely distinct from them.

And besides, there is probably something in the structure of the extremities of a nerve of sensation, which differs from that of a nerve of motion, so as to make it impossible for a nerve of motion to receive the impression producing sensation, even where the impression is made directly upon the muscle itself. There is also probably a different ending of the nerves of sensation and motion in the nervous center, the brain, or spinal marrow, that makes the one kind incapable of performing the duties of the other kind.

262. Products of Nervous Action.—We have thus far contemplated nervous action, for the most part, only in two forms—as producing either sensation or voluntary motion. In sensation the action is from the extremity

of the nerve to the nervous center; but in motion it is from the center to the extremities of the nerves, as they are expanded among the fibres of the muscles. This voluntary motion, you see, may arise in consequence of sensation, as when you withdraw the hand from the fire, if the heat be painful; or it may occur without a preceding sensation, as when the thinking mind wills to perform certain motions for effecting some purpose.

In either case it is supposed that the gray vesicular or cellular substance of the brain is in immediate connection with the mind, and that the white tubular matter of the brain and the nerves serves only for transmission. That is, both in sensation and in motion the effective physical agency is in the vesicular gray substance. This is the working part of the telegraphic apparatus of the mind, while the innumerable tubuli of the white matter of the brain and nerves are the communicating wires.

263. *Involuntary Action.*—Much of the muscular motion of the body is produced without the agency of the will, and sometimes even in opposition to it. This is true of the motions caused by emotions in the mind. For example, the muscular motions in sobbing and in laughing often occur in opposition to the strong action of the will. In this case, the emotion produces its effect upon the gray vesicular substance, and is transmitted through the nerves to the muscles.

There are some common motions which are performed to a greater or less extent without the agency of the will. The muscles which perform them are called involuntary muscles. The muscles of respiration, for example, ordinarily act without our willing them to do so. If they did not, respiration would stop when we sleep, or be stopped by disease. But the will can quicken these muscles in their action. They are therefore not wholly involuntary.

But there are some purely involuntary muscles. The muscular coat of the stomach, which was spoken of in the Chapter on Digestion, as being constantly in motion when the stomach is filled with food, is of this character. No

effort of the will can quicken or retard the action of this muscle. That exceedingly compound muscular engine, the heart, is a collection of purely involuntary muscles.

264. Excitor and Motor Nerves.—We have already alluded to the two roots which unite to make up each nerve that comes from the spine. One of these roots is composed of tubuli through which impressions are transmitted to the spinal marrow; and the other contains tubuli, through which an impression is transmitted from the spinal marrow to the muscles, causing them to contract. Each nerve, then, coming from the spine, is made up of two distinct nerves, or two distinct sets of tubuli. One of these is called an excitor nerve, the other a motor nerve.

In the case of the muscles of respiration, every time that they act, an impression is transmitted from the lungs through an excitor nerve to the spinal marrow, the gray vesicular substance there responding to this impression, and sending in consequence an impression by a motor nerve to the muscles. So, also, the presence of food in the stomach produces an impression which is transmitted through the excitor nerve, and another impression is returned through the motor nerve, exciting the muscular coat to action. And in the act of swallowing an impression is transmitted from the food thrust back into the throat and then impressions are returned to the many muscles engaged in this compound act. The action of the nerves illustrated by these examples is termed their *reflex* action, because the impression transmitted by one nerve to the spinal marrow is *reflected* from it by another.

265. Sensation does not Accompany Nervous Action.—In some cases the impression is accompanied with actual sensation, and sometimes not, the action being confined to the spinal marrow. Thus, in the action of respiration, the impression carried from the lungs by the excitor nerves comes from the presence of dark blood in the lungs. Ordinarily, a mere impression, and nothing like sensation, is transmitted. The respiratory muscles, most of the time, go on to do their

work, in obedience to the impressions communicated from the lungs, without any recognition of the process by the mind.

But when there is embarrassment in the lungs, the quiet process, carried on through the agency of the spinal marrow alone, is not adequate to meet the exigency. In some way, the brain becomes a party in the operation. The act of breathing is now accompanied with positive sensations, and there is a mixture of voluntary and involuntary muscular action.

266. *The Spinal Marrow Performs Two Separate Functions.*—The spinal marrow, then, performs two separate functions—one, by itself, in producing involuntary motion; and another, in connection with the brain, in producing voluntary motion and sensation.

The arrangement by which it does two things which are so different from each other, will be clear to you, if you bear in mind the fact that the spinal marrow, like the brain, is composed of the two nervous substances, the white tubular, and the gray vesicular substance.

When the spinal marrow acts as a mere medium of communication for the brain, the transmission is made directly through the tubes of the white substance to and from the brain—to the brain in sensation, and *from* it in voluntary motion. Thus, when a sensation is felt in the foot, the impression made there is transmitted through the nerve to the spinal marrow, and up through the white part of this organ to the brain. It touches none of the gray substance of the spinal marrow, but goes to the gray substance of the brain. And when the foot is moved, an impression is returned from the brain through the white part of the spinal marrow, and then through the nerve which goes from it to the muscles that move the foot.

But, on the other hand, when the spinal marrow acts by itself, independently of the brain, producing what is called reflex action, the impressions that are transmitted, some of them begin, and some end, in the gray substance of the

spinal marrow. The impression on an excitor nerve ends there, and the impression on a motor nerve begins there, the latter resulting from the former, except when motion is produced by disease in the spinal marrow itself. Thus, in breathing, an impression goes from the lungs through excitor nerves to the gray substance, and that is the end of it; but another impression begins there as a result of it, and is transmitted to the involuntary muscles moving the chest.

267. The Brain Rests—the Spinal Marrow does not.—One marked distinction between the brain and spinal marrow is, that the brain has its intervals of rest; but the functions of the spinal marrow never cease for a moment as long as life continues. In sleep the brain is more or less at rest, and it is in a state of entire torpor when the sleep is profound. But during sleep the heart beats, the respiratory muscles work the chest, and the muscular coat of the stomach churns the food if there be any there.

For these motions, with many others, are dependent upon the spinal marrow, and not upon the brain ; and so, while the brain sleeps, the spinal marrow keeps up the operations of the system that are essential to the continuance of life.

But beside the motions that have been mentioned, as being kept up by the spinal marrow, when the brain is torpid from any cause, there are other motions which can be excited by stimulating nerves that are connected with the spine. For example, the act of swallowing can be produced by pouring a liquid into the mouth, and motion can be produced in the muscles of a limb by irritating the limb at different points. So, too, if a man be paralyzed in his lower limbs by a blow upon the spinal column, these parts, which he cannot move by his will, can be excited to motion by irritation with electricity or other agents.

It may be remarked that the voluntary muscles often act involuntarily. In animals from which the head has been removed, the voluntary muscles can be excited to involuntary action, resembling voluntary movements, although of course with the removal of the head were destroyed all sensation and all exercise of the will. A pigeon, whose cerebrum had

been removed, would fly when thrown into the air, would run when it was pushed, and would drink when its beak was put into the water. There was no sensibility and no will in this case, for these cannot be without the cerebrum. The movements were involuntary, though performed by voluntary muscles. Now as these facts prove that voluntary muscles are, through their connection with the spinal marrow, capable of acting as involuntary muscles also, the question arises whether they do not much of the time act in part as involuntary muscles, and sometimes wholly so.

268. Walking.—When we are walking we use voluntary muscles. But manifestly a distinct act of the will is not put forth for every motion performed in walking. The mind may be at the same time fixed upon something else ; and there seems ordinarily to be only an occasional action of the will, as when we change our course, or when some obstacle is in the way, requiring a variation from the regular consecutive series of movements. There is a distinct action of the will when the movements begin ; but after this the motions seem for the most part almost automatic, and are probably produced by the reflex action of the spinal marrow, the will interfering only when occasion requires.

269. Brain not Directly Essential to Life.
—Many experiments have been tried upon animals with reference to the functions of the brain and of the spinal marrow. It was formerly supposed that the brain was the only center of nervous power, and that it was immediately essential to the preservation of life. But these experiments have shown that this is far from being the truth. The brain, it has been found, has nothing to do directly with the maintenance of life. Animals live for some time after the brain is destroyed. A pigeon was kept alive for some months after its cerebrum was removed.

Its condition was very much like that of a man the functions of whose cerebrum are suspended by the pressure of a fractured portion of the skull. Although, like him, the animal had lost all sensation and voluntary motion, yet, like him, it continued to breathe, and its heart continued

to beat. Of course so extensive an injury of so important an organ will at length cause death ; but life continues long enough in such cases to show that this organ is not immediately essential to its continuance.

270. Upper Part of the Spinal Cord directly essential to Life.—The functions most essential to life, the respiration and circulation, are, as you have seen, kept up by the spinal marrow. The very upper part of this organ is especially devoted to this purpose. You may take out the brain of an animal, and destroy all its spinal marrow, except this upper portion of it, and the animal will still breathe, and its heart will beat. But if you destroy just this small portion of the spinal marrow, though you leave the rest of it and the brain untouched, the animal will die at once from the cessation of the respiration and the circulation.

271. Effects Produced by Cutting the Spinal Cord.—If after cutting off the head of a frog, you divide the spinal marrow in the back, you can still produce involuntary motions in both the upper and lower extremities. But the same irritation will not produce them at the same time in both together, for the division of the spinal marrow in the back separates it into two independent parts. When, therefore, you irritate the upper extremities, the motion is confined to them, and the lower extremities are quiescent. And if you irritate the lower extremities, the motion produced there does not extend to the upper. The division can be repeated with similar results.

If the spinal marrow be divided above and below the origin of a pair of nerves so as to separate this point wholly from the rest of the nervous system, reflex action can be excited in the nerves connected with this point. That is, an irritation of the parts supplied by the excitor nerve of this little segment of the spinal marrow will produce an impression in that segment, which will be reflected by the motor nerve to the muscles.

The gray substance of the spinal marrow may, therefore, be regarded as a chain of little brains, in some measure separate from each other. But while there are thus many centers

of reflex action, there is only one center of sensation and voluntary motion, and that center, the brain, is connected with the mind.

272. Two Systems of Nerves, Cerebro-Spinal and Sympathetic.—The system of nerves which we have been examining is termed the *cerebro-spinal*, from its two great central organs, the brain and spinal marrow. But there is another nervous system, the functions of which are involved in much mystery. It is called the system of the great *sympathetic*, or the sympathetic system. Sometimes it is called the *nervous system of organic life*, because it is intimately and extensively connected with the nutritive processes; while the system that we have been considering is called the *nervous system of animal life*, because it regulates the functions peculiar to animals: sensation, and spontaneous motion.

While the sympathetic system is thus connected with the nutritive processes, it is also supposed to be the means of effecting the sympathetic connection between different parts of the body, and to serve as the medium through which the passions and emotions of the mind produce their effects upon the functions of the different organs. In this system there are many ganglions or little brains, which communicate with each other by nerves.

The structure and functions of the nervous system have thus been described to such an extent as will prepare you for the consideration of those subordinate organs, by which the purposes of this system are accomplished.

CHAPTER XIII.

THE VOICE.

273. The Vocal Apparatus.—The apparatus of the voice is truly a musical instrument. We can see therefore, in its construction and arrangement, the applica-

tion of those principles which usually regulate the production of musical sounds, and which man observes in making the various instruments which his ingenuity has invented to delight the ear.

As the apparatus of the voice is really a wind instrument, we will first develop the principles on which wind instruments produce the various musical notes, and then show you the resemblance between these instruments and the set of organs which are engaged in producing the notes of the voice.

Wind instruments are of two kinds—those that have an inflexible mouthpiece, and those in which the sounds are produced by a vibrating reed. The horn, trombone, trumpet, flute, fife, flageolet, flute-stop and other stops of the organ, &c., are instruments of the first kind.

274. Causes affecting the Variation of Pitch.—The variation of notes produced in these instruments may be thus explained. The column of air contained in the tube is the vibrating body from which proceeds the sound. Any thing, then, that affects the size or form of the column of air affects the note. The length, the breadth, and the mode of producing the vibrations are the cause of the variation of the note. The holes in the side of a flute are for the purpose of altering the length of the confined column of air. In the trombone this is done by sliding one part of the instrument upon the other. The general rule is, the longer is the column of air the more grave

is the note. Thus in the flute, the lowest note that can be produced by the instrument is made by covering all the holes, so that you have a column of confined air the whole length of the tube. The highest note, on the other hand,

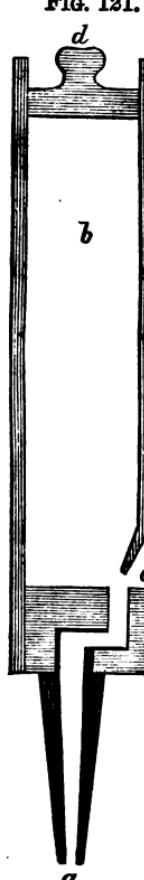


FIG. 121.

which the instrument is capable of producing, is made by so arranging the fingers as to allow the air to escape at the first hole.

275. Size and Width of Vibrating Column of Air affecting the Note.—Fig. 121 is a representation of one of the pipes of the flute-stop of the organ, which is a wooden box, made very much after the manner of a boy's whistle. At *a* is the passage for the introduction of the air; *b* is the inclosed column of air, the vibration of which produces the sound; *c* is the place of escape for the air; and *d* is a movable plug, by means of which the vibrating column of air can be made longer or shorter, according to the note desired. In tuning the organ, if the pipe gives too low a note the plug is moved downward, thus shortening the column of inclosed air, but if too high a note, the plug is raised up.

The same rule applies to the *width* of the vibrating column of air. The wider the column the graver the note, and *vice versa*. Observe, also, that in a long, slender column of air, as in the trombone, by giving the current of air from the mouth a great velocity a high note may be produced; but where, as in the ophicleide, the column is both wide and long, it is difficult to do this, because it is difficult to produce a quick vibration in so large a body of air, with all the suddenness and force with which we can move it.

In those instruments which have no expedient for altering the length of the column of air, such as the common horn, the various notes are produced by narrowing or widening the orifice by the agency of the lips, as the case requires, at the same time giving, by the varied velocity with which the air is forced into the instrument, a quicker or slower vibration to the air. Grave sounds are produced by a wide, and acute by a narrow opening.

276. Reed Instruments.—In *reed* instruments the variations in note are produced in a different manner. The clarionet, hautboy, bassoon, the reed stops in the organ, &c., are instruments of this sort. It is the vibration of the thin plate called the reed that causes the sound. The longer this

plate is, the slower are the vibrations, and therefore the graver is the note. The principle can be well illustrated in the reed stops of the organ. The reeds in the different pipes are made of different lengths, according to the notes which they are to produce. In a reed instrument played by the mouth, the clarinet for example, the rapidity of the vibrations is regulated by the pressure of the lips. In producing a high note the lips press firmly on the reed and leave but a small portion of it to vibrate; while in producing a low note the lips press less firmly on the reed, and leave a large portion of it to vibrate.

277. Stringed Instruments.—This same principle also applies to stringed instruments. Thus in the piano, the grave notes come from long and large strings, while the higher notes come from slender and short ones. In the violin the strings are all of the same length, the larger strings giving the graver notes, and the smaller the higher ones. The notes are varied also in the case of each string by varying the tension. They are varied too while playing on the instrument by varying the length of the vibrating strings by the pressure of the fingers.

278. Tube connected with the Reed.—The reed is frequently connected with a tube. This contains a column of air through which the sound caused by the vibration of the reed must pass. Unless, then, the vibration of this column of air corresponds with the vibration of the reed, it will alter the note. It always does alter the note to some extent. It never raises it, but always makes it more grave. That is, the vibration, in passing from the reed to the column of air, becomes less rapid and coarser, as is always the case when vibration passes from any substance to another.

But the tube is so constructed that there may be as little change in this respect as possible. Holes are therefore properly placed in the side of the tube, so that with the fingers the column of confined air may, in the case of every note, be placed in correspondence with the vibration of the reed.

Suppose the tube to be long and without holes; in this case low notes could be easily produced, but attempt a high note and you would fail. The reason is obvious. The low note is caused by a low and coarse vibration of the reed, for the transmission of which a long column of air is fitted. But if a high note be attempted, the slow vibration of the long column of air *disagrees* with the quick vibration of the reed, and very much flattens the sound as it passes through the tube after coming from the reed.

As already suggested, the object of the tube is to secure the combined effect of a reed and a wind instrument. The tube makes the reed speak, as it is expressed; that is, it gives intensity and an agreeable character to the sound. If you disconnect the reed of the hautboy or bassoon, for example, from its tube, and blow upon it, you can produce all the variety of notes, but the sound is disagreeable; but by connecting the tube with the reed you produce a *compound* sound, as we may call it, which has a sweet and rich melody.

We will now examine the apparatus of the voice, and see how far the principles which have been developed in relation to common musical instruments are applicable to this instrument.

279. Description of the Organ of the Voice.—Just at the root of the tongue, as described in the Chapter on the Bones, is a small bone, shaped so much like the Greek letter *v* that it is called the *hyoid* or U-like bone. The curved portion of this bone is towards the root of the tongue, and its two ends point backward toward the pharynx. With this bone is connected a long cartilaginous tube extending to the lungs, called the trachea, or windpipe. It is through this tube, as you have already learned, that the air goes back and forth from the lungs in respiration and speech. It is composed of a great number of rings of cartilage connected together by membranous parts.

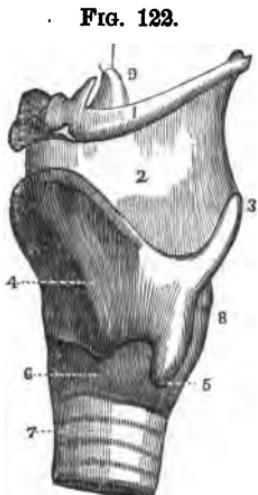
280. Larynx.—But it is the *upper* part of the windpipe, that part which is immediately below the U-like bone, which claims our attention as the seat of the formation of

the voice. This part is called the *larynx*. It is formed of five cartilages, the arrangement of which will now be shown. The largest of these cartilages, the one which forms most of the body of this music-box, as we may call it, is the *thyroid*. It is the *pomum Adami*, or Adam's apple, which is so easily felt in the top of the neck. This cartilage forms the front and sides of the larynx, but it is open behind. The cricoid cartilage is shaped very much like a seal ring, and this resemblance gives it its name. The narrow part of it is situated directly under the thyroid cartilage, in its

front and at its sides, but the broad, seal-like part of it is behind, projecting upward and filling a part of the open space left by the deficiency of the thyroid in the rear. A side view of these parts is given in Fig. 122, in which 1 is the U-like bone; 4 is the thyroid cartilage; and 6 the cricoid. At 8 is the back part of the cricoid, filling up a part of the space in the open rear of the thyroid; 3 is a horn-shaped projection of the thyroid, and five is a smaller one below, projecting over the outside of the cricoid; 2 is a strong membrane or ligament connecting the hyoid or U-like bone with the top of the thyroid; 9 is the epiglottis, drawn up by a hook; and at 7

are the rings of the trachea. The epiglottis is composed in part of cartilage. It is the lid of the larynx, shutting down when we swallow, so that the food or drink may pass over it, and being raised up when we breathe or speak.

There are two small cartilages which are not seen in this figure, called *arytenoid* cartilages, from two Greek words, meaning *ladle* and *shape*, because they bear some resemblance in form to ladles. They stand in the open space in the rear part of the thyroid, on the top of the cricoid



Side view of
THE LARYNX.

cartilage. They are the pillars to which the vocal chords or ligaments are attached behind. These two cartilages are movable, having a regular joint with the upper edge of the cricoid. There are small muscles which pull them in different directions, and thus change the degree of tension and the position of the vocal ligaments, and of course vary the pitch of the sound produced by the vibration of the ligaments.

281. Vocal Ligaments.—Fig. 123, is a diagram showing the arrangement of these ligaments. It represents a view of them as you look down into the larynx, in which *a* is the front of the thyroid cartilage, and *bb* are the two arytenoid cartilages. To these you see are attached two sheets of membrane, which are also fastened all around to the inside of the thyroid. If these movable posts, as we may call them, to which the ligaments are thus attached, be drawn backward, it is obvious that it will make the ligaments more tense. If they are separated from each other, the opening between the ligaments will be widened. If they are brought nearer together, this opening will be narrowed, and the forward part of the free edge of each ligament will be prevented from vibrating, because it will here be brought in contact with the other ligament.

Now there are small muscles which are attached to the arytenoid cartilages for the purpose of moving them as was pointed out. The figure here presented is a mere diagram, to show the arrangement of the ligaments for the production of the various notes of the voice. In Fig. 124 is represented the actual appearance of the ligaments and the arytenoid cartilages, as you look down upon

FIG. 123.

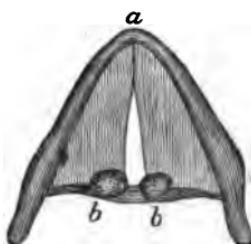
Diagram showing the action of the
VOCAL LIGAMENTS.

FIG. 124.

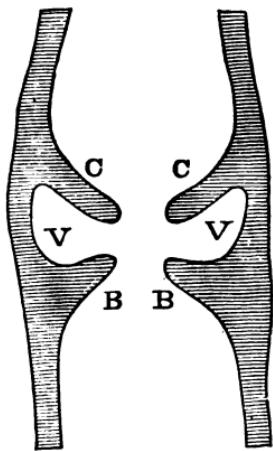


THE VOCAL LIGAMENTS.

them. The ligaments, you observe, are thicker at their free edges than any where else.

The true vocal ligaments have been described. But there is another pair of ligaments directly above them, the space between which is the real opening into the larynx, upon which the epiglottis shuts down when we swallow. In Fig. 125 is a diagram representing the plan of these two pairs of

FIG. 125.



ligaments, as shown by a perpendicular section from side to side. B B represents the vocal ligaments, C C the upper ligaments, and V V the two recesses between them.

282. The Lower the True Vocal Chords.—We know that it is the lower ligaments that are the true vocal chords, because the parts above these, even the upper ligaments, may be all cut away, and yet a vocal sound may be produced; while if an opening be made into the larynx below the lower ligaments the voice will be destroyed.

Magendie, a French physiologist, speaks of a man who, on account of an opening in the larynx, was never able to speak without pressing his cravat tightly against this opening, in order to prevent the air from escaping through it. Many experiments have been tried with the larynx after death to verify the results above stated. The lower ligaments, then, are the vocal chords, by the vibration of which all the different notes of the voice are produced. And the other parts of the vocal apparatus serve only to modify the sound caused by the ligaments. The lungs act merely as the "wind-chest," to hold the air which, being forced out, strikes on the ligaments, and makes them vibrate.

283. Principles of Musical Instruments applied to the Vocal Apparatus.—Let us now apply to this apparatus the principles already developed, as

regulating the variation of note in common musical instruments. The size of the aperture, through which the sound is thrown out, influences the note—of this fact we have a familiar example in whistling. And as you have seen that the size of the opening between the vocal ligaments is varied by the muscles moving the arytenoid cartilages, this variation must have an influence upon the note of the voice.

But this is not the only cause of the variation of the note. As shown in relation to the reed, and to the strings of stringed instruments, so also here, the larger and less tense are the vibrating bodies, the vocal chords, the graver is the note. You have seen how these chords or ligaments are varied in tension by the action of the muscles that move the arytenoid cartilages. You have also seen that, as these cartilages are brought near together by the muscles, the length of the free vibrating edges of the ligaments is shortened, because the edges are brought together in their anterior part (Fig. 123).

Magendie verified this by observation. He opened the throat of a noisy dog in such a way that he could look directly upon the vocal ligaments. When the sounds were grave, he observed that the ligaments vibrated in their whole length, and that the air passed out through the whole length of the chink between them. But when the sounds were on a high note, the ligaments did not vibrate in their anterior part, but only in the posterior, and the air passed out only at the open part.

284. Resemblance between the Instruments of the Voice and Common Musical Instruments.—The sound as it comes from the larynx passes through a tube, just as the sound coming from a reed does in a reed instrument. In other words, there is a body of inclosed air extending from the larynx to the outlets of the mouth and nose, which vibrates in transmitting the sound from the larynx. This body of air is not so simple in its form as that which is inclosed in the tube of common reed instruments. It has three outlets, the mouth and the two nostrils. The sound of the voice seldom comes out

from the orifices of the nostrils, but almost always from the mouth. In humming it comes altogether from the nostrils. In ordinary speaking and singing the cavities of the nose act as reverberating cavities, the sound which reverberates there issuing from the mouth.

285. Tube of the Vocal Apparatus like that of a Reed Instrument.—You have seen that the tube connected with the reed in the reed instrument is so constructed, that the length of the confined column of air can be changed, in producing the different notes; the vibration of the air thus being brought into correspondence with that of the reed.

If you place your finger on the front of the larynx, and then sound various notes, you will feel the larynx rise when you sound a high note, and fall when you sound a grave one. The object of this movement is to alter the distance from the larynx to the outlet of the mouth—in other words, to alter the length of the column of air in the tube—so that it may correspond in its vibration with the vibration of the vocal chords. But the size of this column of air is altered in another way. It is altered in its *width*, which is quite as effectual in changing the vibration as an alteration of length. The tube of the vocal instrument you readily see can be altered in its width by the muscles of the throat and mouth.

The object of the tube of the reed instrument is to make the reed speak, as it is termed; that is, to give intensity and an agreeable character to the sound. If the voice should come directly from the larynx without passing through the tube attached to it, it would be as disagreeable as the sound of a reed when separated from its tube.

The voice gets most of its melody after it is made in the larynx, as it passes out through the column of air in the throat and mouth. And it is the variations of this tube produced by the muscles that surround it that give to the voice its variety of tone as well as its melody, thus constituting one of the great excellencies of the vocal instrument in comparison with all common musical instruments.

286. Delicacy of the Action of the Vocal Muscles.—To have some conception of the variety of the motions of the muscles concerned in the modulation of the voice, listen to some singer whose voice can command with ease and freedom a great extent of the scale. For every note that you hear there is a distinct and particular adjustment of the vocal ligaments, and of course a particular degree of contraction of the little muscles that move them.

It is calculated that the ligaments vary in length only about the $\frac{1}{4}$ of an inch in producing all the notes of the voice. Now the natural compass of the voice (that is, its range from its lowest to its highest note) in most singers is about two octaves or 24 semitones. Within each semitone a singer of ordinary capability can produce 5 or 6 distinct notes; so that for the whole number of notes that he can sound distinctly 120 is a moderate estimate. He therefore produces 120 different states of tension in the vocal ligaments. And as the variation in their length for passing from the lowest of these 120 notes to the highest is only the $\frac{1}{4}$ th of an inch, the variation required to pass from one note to another will be only the $\frac{1}{60}$ th of an inch. A very expert singer can produce a much more delicate action than this, and distinctly appreciate the result by his ear.

287. Importance of Keeping the Chest Full of Air.—The skillful singer or speaker exhibits much skill in managing the muscles of the “wind-chest.” He keeps it all the time well supplied with air, so that but a comparatively slight action of the expiratory muscles will suffice to throw the air against the vocal ligaments with the requisite force. But an unskillful singer or speaker much of the time has his chest poorly supplied with air, and so speaks or sings, as it is expressed, from the top of the chest. It costs him, therefore, so much labor to throw out the air with sufficient force, that he is soon tired out.

The necessity for keeping the chest full of air, in order to work the vocal apparatus easily, may be illustrated by reference to the bagpipe. If the bag containing the air be well filled, a slight pressure of the arm upon it will force the air

through the pipe with sufficient rapidity to produce the sound. But if the bag be flaccid from the little quantity of air in it, a very strong pressure of the arm will be required to produce the same effect.

288. Tiring out the Vocal Muscles.—But it is not the muscles of the chest only that are tired out in the unskillful singer or speaker, but also the muscles of the larynx and the throat. And a frequent tiring of these muscles weakens the parts, and often at length produces disease. Much of the throat-disease of public speakers comes from this cause, and is a nervous disease, the affection of the lining membrane of the throat being often a mere accompaniment.

This result is more apt to occur when the nervous force of the system generally is impaired. It is also more apt to occur in those who speak in a uniform and somewhat monotonous manner, than in those who speak with much variety. A continuation of precisely the same muscular effort for any length of time is apt to produce painful exhaustion, while a much greater amount of *varied* muscular effort may be put forth without weariness, or even with pleasure.

289. Parts Engaged in the Articulation of the Voice.—We will now observe the agency of the different parts of this compound vocal tube in the articulation of the voice. Each letter, whether it be a vowel or a consonant, requires a particular position of the different parts of the vocal tube. In some letters the tongue is the chief agent in articulation, in others the lips, in others the teeth, in others the palate, and there are some in the formation of which the cavities of the nose have an important agency.

290. The Tongue less Essential than Commonly Supposed.—The tongue has been considered so essential to speech, that tongue and language are often used synonymously. But though it does perform an important part in articulation, it is not absolutely essential. A boy, who lost his tongue by disease at the age of eight years, was

exhibited publicly because he could talk without a tongue. A girl, who lost from disease the whole of her tongue, together with the uvula (the little round body which hangs down from the middle of the arch of the palate), could talk and swallow as well as any one. So perfect was her articulation, that she could pronounce with exactness those letters which commonly require the agency of the tip of the tongue. She could sing finely, articulating with the same clearness as when she talked.

291. *Dentals.*—Some of the letters are formed principally by the teeth, as *c*, *t*, *s*, *z*. They are therefore called *Dentals*. It is the too frequent and bungling employment of some of these which constitutes lisping. Those who have a tongue too large for the mouth are apt to lisp. In advanced age, when the teeth are lost, we find this defect of lisping. The reason is obvious. When the teeth are gone, the sockets gradually become obliterated, and that part of the jaw-bone where the teeth were, of course diminishes in size, making the mouth too small for the tongue.

292. *Labials.*—The letters, in the articulation of which the lips takes the lead, are *b*, *p*, *m*, *f*, *v*, *w*, &c., and are called *labials*. Children, when they first begin to talk, use labials freely, because they can see in others the motions necessary for their pronunciation, and are led to imitate them. Hence the endearing terms used by the child to the parent are, in all languages, or nearly all, composed of labials and vowels. And, too, it is from the delight which the child takes in repeating over and over these terms, that we have the word *papa* and *mama*, instead of *pa* and *ma*. The same thing can be observed in other languages as well as the English.

293. *Reverberation in some Letters in the Nasal Cavities.*—The nasal cavities, it is obvious, must have a great influence in articulation. The letters *m* and *n* are partly nasal. In pronouncing *m* at the end of a syllable, as *am*, *em*, or *om*, we close the lips, and the sound issuing from the larynx reverberates in the cavities of the nose. You can perceive this reverberation by pressing gently upon the

nostrils with the fingers while pronouncing this letter. The same can be said of *n*, except that in pronouncing it we press the tip of the tongue against the roof of the mouth just behind the front teeth, preventing the passage of the air out through the mouth in this way, instead of doing it by closing the lips, as in articulating *m*.

294. Speaking through the Nose.—In what is commonly called speaking through the nose the reverberation mentioned above is disagreeably strong. The popular idea of it is incorrect, for this fault occurs in those who have some obstruction to the free passage of the air through the nose. This obstruction acts like the pressing of the nostrils with the fingers, confining more or less the body of air contained in the nasal passages. It is the vibration of this air thus partially confined in tortuous passages that produces the nasal twang. Any thing, therefore, which prevents the free outlet of the air from the nose will occasion it. Pressing the fingers on the nostrils while speaking will produce it.

295. Whispering.—When no sound is produced by the ligaments of the larynx, as is the case in whispering, the noise produced by the passage of the air through the cavities of the vocal apparatus can be so articulated, as to be heard distinctly at a considerable distance. Persons, therefore, who have entirely lost the voice can converse. In whispering the vocal ligaments are relaxed as they are when we simply breathe. But the sound of whispering has its high and low notes like the vocal sound. The variation of note is caused by variation of the size of the column of air contained in the vocal tube.

296. Contrivances to Imitate Articulation.—Various attempts have been made to imitate the articulation of sounds by mechanism, but with very limited success. In 1779 a prize was offered by the Academy of Science at St. Petersburg, for the best dissertation on the theory of vowel sounds, and it was awarded to G. R. Kratzanstein, an account of whose experiments was published in the Transactions of the Academy. He found that the sound of the four vowels, A, E, O and U, might be produced by blowing

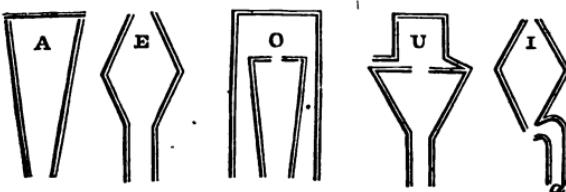
through a reed into tubes, the forms of which are represented in Figures 126, 127, 128, 129 and 130, and that the

FIG. 126.

FIG. 127.

FIG. 128.

FIG. 129. FIG. 130.



sound of I, as pronounced by the French and other European nations, could be produced by blowing into the tube, Fig. 130, at *a*, without using the reed.

CHAPTER XIV.

THE EAR.

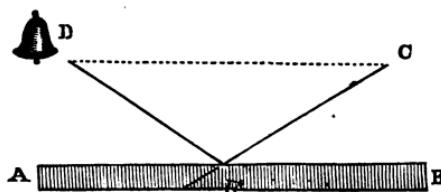
IN the last chapter the production of sound by the vocal apparatus was mentioned. In this chapter it is proposed to show how the impression of sound is transmitted to the brain, in order to produce the sensation of hearing.

297. Difference between a Sound and a Noise.—Sound may be produced by the vibration of any substance; though some bodies are better fitted to produce it than others, and are therefore called sonorous. When the vibrations which cause sound are equal, a *musical sound* results; but if they are unequal, we have a discordant sound, or what we ordinarily call a *noise*. Sound is transmitted from the point where it originates, in all directions. And its vibrations gradually lessen, just as the ripples lessen which are produced by dropping a stone into the water.

298. Reflection of Sound.—The vibrations of

sound are reflected by objects against which they strike. For this reason the voice can be heard at a much greater distance if it be transmitted along a wall than when it is uttered in an open space. This may be illustrated on Fig. 131. Let A B represent a wall, and C the position of the

FIG. 131.



ear. If the bell at D be rung, besides the vibrations which come to the ear at C in the direct line C D, a vibration striking the wall at F will come to the ear in the line F C, and the same can be said of other points along the wall. An accumulation of vibrations, therefore, comes to the ear at C, which therefore receives a louder sound from the bell than it would if the bell were rung in a perfectly open space. For the same reason a speaker can be heard much more easily within walls than in the open air. The sound is reflected, and, therefore, in some measure concentrated by the walls.

299. Speaking Tube.—In speaking tubes this reflection and concentration are carried to a still greater extent. Sound can in this way be heard at a great distance from its source. M. Biot found that when he spoke in a whisper at one end of a tube, over three thousand feet in length, he was distinctly heard at the other end; so entirely do the walls of the tube prevent the diffusion of the vibration in the air around. Speaking tubes are therefore used to a great extent in large manufactories, where directions need to be given continually to workmen in different parts of the establishment. The flexible tube, now so commonly made use of by deaf persons, furnishes another illustration. The

vibrations of the voice received by the trumpet-shaped end are transmitted through the tube to the ear.

300. Difference in the Transmission of Sound through Solids, Liquids and Gases.—Sound may be transmitted through any substance, whether it be solid, liquid, or gaseous. It cannot be transmitted through a vacuum, for there is nothing there to vibrate. Sound differs in this respect from light, which passes as readily through a vacuum as it does through any transparent substance.

A pistol fired on the summit of a mountain, gives not nearly so loud a report as when it is fired in the valley below. The more solid the medium is for the transmission of sound, the more readily is it transmitted. The scratching of a pin at the end of a long log may be heard by the ear applied to the other end, although it can not be heard through the air, at even the distance of a few feet. A deaf gentleman, resting the bowl of his pipe on his daughter's piano-forte as he smoked, found that he could hear the music with great distinctness; and many deaf persons can hear conversation, by holding a stick between their teeth, while the other end rests against the teeth of the person speaking.

Water is a much better conductor of sonorous vibration than air, though it is not so good an one as a solid substance. The force of the vibration is lessened more gradually in water than in air, and its rate of progress in water is, according to Chladni, 4,900 feet in a second, or between four and five times as great as in air.

301. Sonorous Vibration does not pass readily from one Medium to Another.—Thus, although the scratch on the log is heard so easily by the ear at the other end, if the ear be removed a little from the log, it does not hear the sound, because the vibration is so much lessened in passing from the solid wood to the air. It is clear that the more unlike two substances are, when sound passes from one to the other, the more will the force of the vibration be lessened; for the more unlike they are, the less easily will the one take the vibration from the other.

For this reason, a sonorous vibration, produced in a solid body, may be transmitted to water with much less loss of intensity or force, than occurs when it is transmitted to air. And it may be remarked in this connection, that when vibrations are transmitted to a fluid, from air or from a solid, an intervening membrane is of essential service, for it presents a firm surface upon which the vibrations can be received.

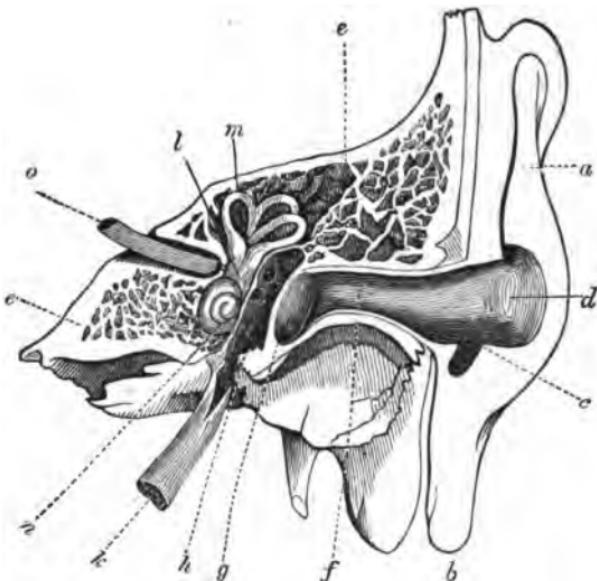
302. Hearing a Compound Process.—The vibrations of sound, passing into the ear by a tube, strike at the bottom of that tube upon a membrane called a drum. The air can go no farther, for this drum is perfectly air-tight. It communicates its vibrations, however, to the drum, which transmits them to a chain of four little bones, the last of which transmits them to another drum, covering an opening into various winding passages in solid bone. In these passages is contained a limpid fluid, which is put in motion by the vibrations of the drum last mentioned.

So much for the mere mechanical part of the process. In the winding passages are spread out the minute fibres of the nerve of hearing. The vibrations of the liquid in these halls of audience make an impression upon these nerves, which is communicated to the brain through the trunk of the nerve, and this completes the whole process necessary to the production of the sensation of hearing.

303. The Parts of the Apparatus of Hearing Described.—The parts of the apparatus of hearing may be seen in Fig. 132. The internal portions are made rather larger than natural, in order that the construction of the ear may be clearer. At *a b c* is the external ear; at *d* is the entrance to the tube of the ear, *f*; *g* is the drum of the ear at the end of this tube, called the membrane of the *tympanum*; *h* is the cavity of the *tympanum*, the chain of bones which it contains being left out, so that the plan of the apparatus may be more clear to you; *k* is the Eustachian tube, which makes a communication between the back of the throat and the cavity of the *tympanum*; *n* is a part of the winding passages, shaped like a snail's shell, and therefore called the *cochlea*; at *m* are three other winding passages,

called, from their form, *semi-circular canals*; and at *l* is the *vestibule*, or common hall of entrance to all these winding passages.

FIG. 182



VERTICAL SECTION OF THE ORGAN OF HEARING.

In the wall of the tympanum, on the side opposite to the drum of the ear, you see two holes. These open into the winding passages, the larger one into their vestibule or entrance hall. Each of these holes is covered by a membrane, and to the membrane of the larger one is attached the last of the chain of bones. At *o* is the trunk of the nerve of hearing, and at *e e* is the bone that encloses these parts, which is so hard that it is called the *petrous*, or rock-like bone.

304. External Ear.—The object of the external ear is to collect the waves of sound, and direct them into the tube of the ear. There have been many speculations in regard to the use of the prominences and ridges of the

external ear, but they are fanciful and groundless; and its surface is thus diversified, probably for the sake of comeliness. If the object were to give it the best shape and construction for collecting the vibrations of sound, it would have had a different shape altogether, and would have been provided with muscles which could turn it in different directions, as is the case with many animals. The shape of the external ear is much better in many animals than it is in man, if we consider its object to be merely the collection of the waves of sound. The endowment is in this case, as well as in every other, according to the necessities of the case.

305. Tube.—The tube of the ear is about an inch long in the adult. It is formed of cartilage like the external ear, and ends at the drum. At its entrance are hairs which afford some protection against intruders. But the chief protection is the bitter wax, which is secreted by little glands, situated in the skin of the tube. The odor from this secretion so effectually keeps out the insects from this open entrance, that it is quite a rare occurrence to have an insect get into the ear. And when one does get in, the wax envelopes him, and commonly soon destroys him.

306. Drum and Bones.—The drum of the ear, which makes the closed end of the tube above described, as seen at *g*, Fig. 132, is very thin and transparent. On the other side of it is the cavity of the tympanum *h*. In this

cavity are the four bones. These are represented in Fig. 133, enlarged so that you can see their shape distinctly. They are named from their shapes.

They are the *malleus* or hammer *m*; the *incus* or anvil *i*; the *os orbiculare*, or round bone *o*, the smallest bone in the body; and the *stapes* or stirrup-bone.

The long handle of the hammer *h* is fastened to the middle of the drum of the ear. The little round bone is fixed between the slender end of the anvil, and the top of the

FIG. 133.



stirrup-bone. In Fig. 134 you have a representation of these bones, together with the drum of the ear. While the end of the handle of the hammer is fastened to the middle of the drum, the base of the stirrup is fastened to another drum, covering the hole or window, opening into the vestibule of the winding passages.

There are three very delicate muscles which move these bones. One of them relaxes the drum of the ear, and another makes it more tense; and thus the drum is put into the right states of tension, to accommodate it to the various kinds of vibration that come to it. This is a matter of some importance, for it is plain that while a relaxed drum can vibrate properly to grave sounds that enter the ear, it must be tense, in order to respond properly to the vibrations of the air in the higher notes.

307. Eustachian Tube.—The cavity of the tympanum (*h*, Fig. 132) containing the little bones, which is beyond the drum, communicates with the mouth by the Eustachian tube *k*. If you shut your mouth, and close the nostrils with the fingers, and then perform the action of blowing, you will feel the air enter the Eustachian tubes, and fill the cavity of the tympanum. The chief object of this communication is to have air on the inside as well as the outside of the drum, so that it may vibrate freely.

308. Winding Passages of the Internal Ear.—These are inclosed, as already stated, in the most solid bone in the body. They are called together, very appropriately, the *labyrinth*, sometimes the *internal ear*. This is really the essential part of the apparatus. Here are the true halls of audience, where the nerve receives the messages from without, and transmits them to the brain. The drum of the ear and the chain of little bones may be destroyed, and yet, if these winding passages remain entire, with the membranes over the two windows that open into them, the hearing will not be lost; though it will be less perfect than

FIG. 134.

DRUM OF THE EAR
with the bones.

it is when the whole of the apparatus is there, and in good order.

309. The Winding Passages.—The labyrinth is represented much magnified in Fig. 135. The middle part of it, *v*, is the *vestibule*. From this go out the *semi-circular canals*, *x*, *y*, *z*, on the upper side, and on the lower the winding passages of the cochlea, *k*.

FIG. 135.



in the wall of the tympanum, opposite to the drum of the ear.

310. Principles of Transmission of Sound observed in the Arrangement.—It will be proper to say a word here in relation to the choice of a fluid, instead of a solid or an aeriform substance, as the medium through which the impression of the vibration of sound is communicated to the nerve. It is better than a solid would be, because no arrangement of a vibrating solid with the minute fibres of the branches of the nerve could be effectual, and at the same time so little liable to derangement, as the arrangement of nervous fibres immersed in a liquid, and the whole inclosed in solid walls of bone.

It is better than air would be, for at least two reasons. 1st. The vibrations of sound are communicated with much more ease and rapidity through water than through air. This we see to be a consideration of some importance, when

we look at the complicated and winding passages that contain the fluid.

2d. There is not so much loss in the force of the vibration in the transmission from the solid stirrup-bone through the membrane to the fluid, as there would be if the transmission were to air.

311. Steps of the Process of Hearing given in their Order.—Having thus described the parts of the organ of hearing, we will trace the steps of the process of hearing, as it must occur in the case of every sound that we hear. The vibrating air enters the tube of the ear, and, reaching the drum, produces a vibration there. This vibration is communicated to the chain of bones, which pass it on. It is transmitted from the last of this chain of bones, the stirrup-bone, to the membrane covering the *fenestra ovalis*, and from this to the fluid contained in all the passages of the labyrinth.

The vibration goes through all the semi-circular canals in one direction, and in another up one gallery of the cochlea, and down the other. In all these cavities, are spread out in various ways the filaments of the nerve which receive the impression of the vibration. This impression is transmitted from the extremities of the nerve, through its trunk, to the brain, where the mind receives it. All this together constitutes hearing; and all of it occurs in the case of any sound which we hear, however closely it may follow any other sound.

Most of our hearing is done precisely in the way described, but not all. We sometimes hear directly through the bone surrounding the labyrinth. If you place a watch between the teeth, you hear the ticking; and it gives a very different sound from what it does when held to the ear, because the sonorous vibration is transmitted directly from the teeth through the solid bones of the skull.

312. Complicated Apparatus, producing Simple Results.—Though the apparatus of the ear is complicated, the mechanical result is a simple one—it is a

mere trembling of a fluid inclosed in winding cavities of bone. But simple as the result is, it is made, through the beautiful nervous connections of the ear with the brain, one of the chief inlets of knowledge to the mind.

Thus intimately in the human body are the simplest mechanical results connected with the complicated and diversified operations of the mind. In the process of hearing the drum of the ear is to be considered one end of the apparatus, and the gray portion of the brain the other. The drum simply vibrates; and instantaneously the mind receives a distinct impression from the vesicles of the gray matter. And thus is the communication established between the immaterial mind, and the vibrations of the material substances with which it is surrounded.

CHAPTER XV.

THE EYE.

313. Seeing, a Compound Process.—The sensation of sight is the result of a compound process, which may be divided into two distinct parts. The one part is purely mechanical, and the apparatus for it is constructed according to the common principles which we find illustrated in optical instruments. The object of its arrangements is to form distinct images of objects in the back part of the eye. The other part of the process is executed by the nerve of vision, called the optic nerve.

314. Refraction of Light.—The rays of light coming from any luminous point go in straight lines in all directions, just as the vibrations of sound do, and, like them, become less intense the farther they are diffused. When

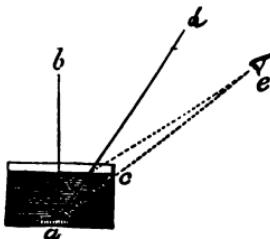
they pass from one medium into another they are bent out of their straight course, or *refracted*, unless they pass from one to the other in lines perpendicular to the surface of the medium which they enter.

315. Refraction as Light passes from a Rarer into a Denser Medium, or Vice Versa.

—This may be illustrated by the following experiment. Place a coin, *a*, in the bottom of a basin, as represented in Fig. 136, and then withdraw from it so far that the coin may be hidden from your eye by the edge of the basin, as represented in the figure. Keeping your eye fixed in that position, pour some water into the basin up to the level, *c*. The coin will again become visible to your eye. The reason is, that the rays of light, as they come from the water into the *rarer* medium, the air, are refracted or bent downwards, that is, *from* the perpendicular. The effect of this may be seen in the figure. A ray of light, coming from the coin in the direction *a*, *d*, does not pass to *d*, but is bent downward, and so passes to the eye at *e*. The coin, therefore, is seen by the eye at *e*, but it is not seen in its true direction from the eye, which is in the line *e*, *c*, *a*, for we always judge of the place of an object by the direction in which the rays from it strike the eye. The only point from which the eye can see the coin in its true position is at *b*, in a perpendicular line directly over it. A ray that passes from one medium to another in a line perpendicular to the surface of the medium into which it passes is not bent out of its course.

While rays that pass from a dense medium into a rarer, as from water into air, are bent *from* the perpendicular, those, on the other hand, which pass from a rarer medium into a denser, as from air into water, are bent *towards* the perpendicular. Thus if in Fig. 136 *a* be the position of the eye of a fish, and where the eye is, at *e*, there be an insect, the fish

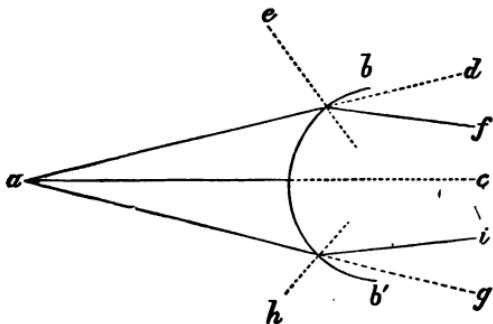
FIG. 136.



can see it, because the ray that strikes the surface of the water, c , is refracted or bent towards the perpendicular line, b , a . He does not see the insect, however, in its true direction, a , c , e , but it appears to him to be at d .

316. Refraction by Convex Lenses.—When light passes from one medium into another of different density which presents a convex or concave surface, instead of a flat one, a very great change is produced in the direction of its rays. Thus suppose, as represented in Fig. 137, three

FIG. 137.

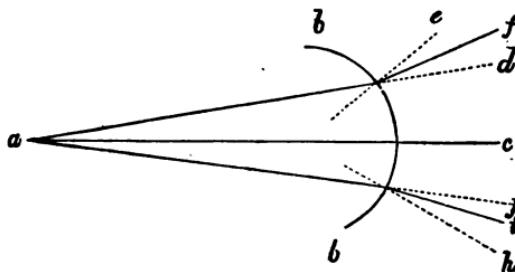


diverging rays coming from a point, a , through the air, enter a *convex* surface of glass, b , b' . The central ray a , c , enters the glass in a direction perpendicular to its surface, and therefore does not bend from its course. But the ray a , d , enters very obliquely, and is bent towards the perpendicular at that point, e , and passes on in the direction f . So likewise the ray a , g , is bent towards the perpendicular h , and passes on in the line i . These rays *diverging* in the air have become converging in the glass, and the point at which they meet is called the *focus*. To this point all the other rays entering the convex glass converge also.

317. Refraction by Concave Lenses.—But if the surface of the glass be *concave*, as represented in Fig. 138, the diverging rays which enter it will be made to diverge still more. The ray, a , c , being perpendicular to the surface is unchanged in its course; but the ray, a , d , is bent

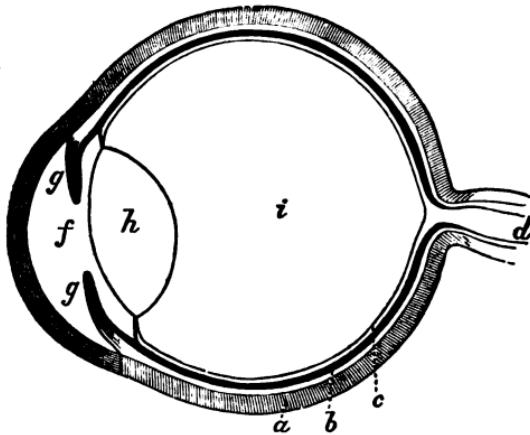
towards the perpendicular, e , into the line f , and the ray, a, j , is bent towards the perpendicular h into the line i .

FIG. 138.



In the case of both the concave and the convex lens, the greater the curvature, the greater is the change of direction in the rays. The greater the curvature, therefore, the sooner are the rays brought to a focus in the case of the convex lens.

FIG. 139.



DIFFERENT PARTS OF THE EYE.

318. Description of the Coats of the Eye.—The arrangement of the different parts of the eye is shown by Fig. 139, which is a mere map of a section of the eye, through

its middle part from front to rear. It is intended to represent the arrangement of the parts distinctly, without strict regard to proportion. The eye has three *coats*, as they are called. At *a* is the thick strong white coat, called the *sclerotic* coat, from a Greek word meaning *hard*. This, which is commonly called the white of the eye, gives to the eyeball its firmness. Into it the *cornea*, *e*, fits like a watch-glass into its case. The sclerotic and cornea then make the outer coat of the eye.

Next comes the *choroid* coat, *b*. This is a very vascular coat, containing the minute branches of blood-vessels which nourish other parts of the eye. It is of a dark color, for reasons which will be stated in another place. Its color is owing to coloring matter contained in pigment cells, which lie along on the inner surface of this coat, next to the inner coat of the eye, the *retina*, *c*. The retina is a thin membrane, being principally composed of the expansion of the optic nerve, *d*.

319. *Humors of the Eye.*—The eye has three *humors*, as they are termed. The first is the *aqueous* or watery humor, *f*, which is in a chamber between the transparent cornea, *e*, and the *crystalline humor*, or lens, *h*. This chamber is divided into two parts by the iris, *g*, *g*, the pupil being the circular communicating door between them. The part of the chamber which is in front of the iris is much larger than that which is behind it. The crystalline humor, or *lens*, as it is more often called, has the consistency of half dissolved glue. At *i* is the *vitreous humor*, filling up a large part of the cavity of the eye. It is called vitreous from its glassy appearance. It is a clear jelly-like substance, having about the tenacity of white of egg. It is contained in an exceedingly thin and delicate sac, and this is divided into cells which contain the liquid.

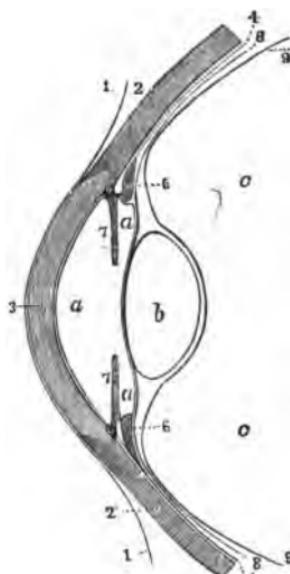
320. *Arrangement of the Front Part of the Eyeball.*—Fig. 140 is a map of the front part of the eye, in which the parts are more minutely delineated than in Fig. 139. At 2 is the sclerotic coat; 3, the cornea; 5, the crystalline lens; 6, 6, 6, the aqueous humor; 7, 7, the iris; 4,

the choroid coat; 8, the retina; *c, c*, the vitreous humor; and 9, the sac containing it. Around the inside of the chamber containing the aqueous humor is a very thin membrane (represented as you see by a line), which secretes the humor. In this membrane, as in the case of every other closed sac in the body, there are both exhalants and absorbents, so that the fluid may be changed as necessity requires.

There is another thin membrane of the eye which has not yet been described. It is represented by a line, 1, in the figure. It is the *conjunctiva*, so called because it unites or *conjoins* the ball of the eye with the eyelids. It covers the cornea, passes back a little way on the white of the eye, and then turns forward to line the eyelid. It is the seat of the most common form of inflammation in the eye. It is very vascular, as is shown by its distended vessels when it is inflamed. It is exceedingly sensitive, and hence the great pain which is occasioned by any thing, even the smallest mote, that gets into the eye.

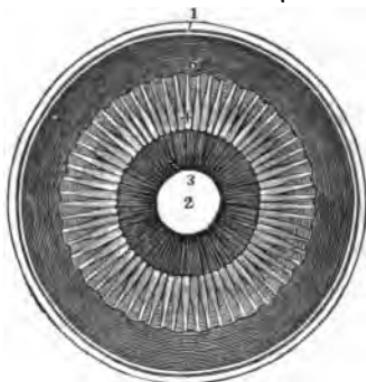
321. Ciliary Processes.—At 6 in Fig. 140, is one of the *ciliary* processes, as they are called, from their resemblance to the eyelashes. There is a circular row of them, numbering from sixty to eighty, so arranged as to resemble the disk of a radiated flower. In Fig. 141 they are represented as they appear in looking at them from behind, the back part of the eye being removed. At 1 is the divided edge of the three coats; 2, the pupil; 3, the iris; 4, the ciliary processes. At 5 is the anterior edge of the retina, at the beginning of these processes, presenting, as you see, a scalloped appearance. The processes come from the

FIG. 140.



choroid coat, and are united at their origin by a ring of ligamentous substance to the sclerotic coat. The exact operation of this beautiful mechanism is not known, but

FIG. 141.



CILIARY PROCESSES.

it is pretty well ascertained, that muscular fibres are so connected with these processes, that when they contract they draw the crystalline lens forward.

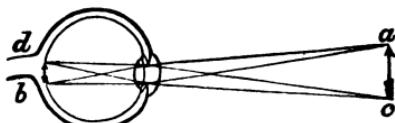
322. Object of the Apparatus to Form Images of Objects on the Retina.—The object of all this apparatus, here described, is the formation of images of objects in the back part of the eye upon the retina, so that the optic nerve expanded there may carry impressions from them to the brain. The rays of light coming from an object pass through first the cornea, then the aqueous humor, then the crystalline lens, and lastly the vitreous humor to the retina, where they, so to speak, daguerreotype the object. The fact that such an image is formed has often been proved by observation on the eyes of animals.

If the eye of a rabbit be cleansed from the fat and muscles at its back part, and a candle be held in front of it, you can see the image of the candle through the sclerotic coat, formed upon the retina. So if you take the eye of an ox, and carefully pare off the back part, so as to leave it very

thin, a distinct image of any thing placed in front of the eye may be seen at the back part.

323. Images on the Retina Inverted.—The image, however, will be inverted, as represented in Fig. 142.

FIG. 142.



For the sake of clearness two rays only are represented as coming from each of the two ends of the object, *a*, *c*. These rays cross each other in the middle of the eye, those from *a* being brought to a focus at *b*, and those from *c* at *d*. As all the other rays, coming from other points in the object, are refracted in the same manner, a complete *inverted* picture of it is thus formed. The cornea is, as you see by Fig. 139, more convex than the sclerotic coat, so that it may act with some power as a lens in making the rays converge.

324. Iris.—The iris is a circular curtain with a round opening in its center, called the pupil. The latter can be varied in size to a considerable degree. On the iris depends what is called the color of the eye, which is various, as blue, nearly black, gray, hazel, &c. The chief office of the iris is to regulate the quantity of light that enters the eye. When the light is obscure, the opening in the iris is widely dilated; but when there is much light it is contracted; and if the light be excessive, it is contracted almost to a point. These motions are effected by peculiarly arranged muscular fibres, of which the iris is in part composed. There are two sets of fibres, the circular and radiated, as represented in Fig. 143. When the circular fibres contract, the pupil is contracted; and when, on the other hand, the radiated fibres contract, the pupil is dilated.

325. Crystalline Lens.—The crystalline lens is the

FIG. 143.



chief agent in the eye in concentrating the rays of light by refraction. In Fig. 144 you have a side view of it. Its anterior part, 1, is less convex than its posterior, 2.

FIG. 144.



Crystalline Lens.

In Fig. 145 is a magnified view of the lens hardened in spirit and cut open, so as to show the different layers of which it is formed. The layers are more and more hard as you go towards the center. The object of this arrangement and of the peculiar shape of the lens, is not as yet understood.

326. Choroid Coat.—The choroid coat (*b*, Fig. 139)

FIG. 145.

contains quite a large share of the minute blood-vessels and nerves of the eye, and serves for a medium by which they pass to other parts of this organ. But it serves another important purpose by means of its dark pigment. It makes a dark chamber of the back part of the eye where the optic nerve is expanded. The object of this is to secure distinctness in the images formed upon the retina.

327. Want of Pigment in the Choroid of the Albino.—The pigment is deficient in the iris of the albino; and the bright red or pinky hue of the iris in his case is owing to the blood in the minute blood-vessels, with which this part is so well supplied. Those animals that use their eyes mostly in daylight have the pigment of the choroid of the darkest color; while, on the other hand, those that need to see most clearly at night, as the owl, either have none of this pigment, or have it of a very light color.

328. The Retina.—The retina is a soft grayish delicate membrane, formed chiefly of the expansion of the optic nerve. Here the images are formed, and the minute fibres of nerve in this membrane receive impressions from these images, which are transmitted to the brain by the



trunk of the nerve. This nerve has the same relation to light that the nerve of hearing has to sound, the nerve of smell to odors, or the nerve of touch to the qualities of bodies that we feel. And it is curious to observe that the termination of the nerve of sight on the surface of the retina is arranged in *papillæ*, just as the terminations of the nerves of touch are. In Fig. 146 is represented a portion of the retina of a frog magnified three hundred times. The upper rows of papillæ, which are without dots, are seen sideways.

329. Spherical Aberration.—

There is a defect in the operation of lenses in optical instruments, which is termed *spherical aberration*. This can be explained on Fig. 147, which represents a lens, L, L', with some of the rays as they pass through it. Now the rays R' R'' R''' are brought to a focus at F; while the rays R L and R''' L' come to a focus much nearer, at l. It is found by

FIG. 146.

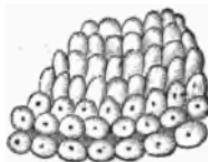
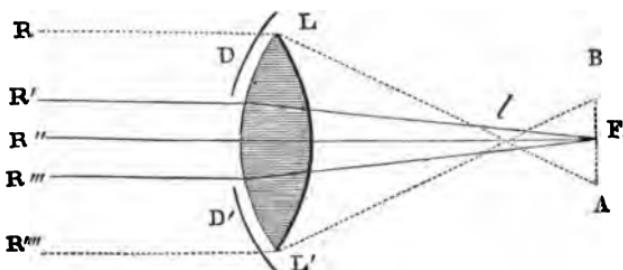


FIG. 147.



experiment, that if the central portion of the lens be covered, so that the rays R' R'' R''' cannot pass, a distinct image will be formed on a screen put at l. And, on the other hand, if the outer portion of the lens be covered, so that the outer rays are intercepted, then the middle rays, R' R'' R'' will form an image on a screen at F. But if the whole lens be used, no distinct image is formed, anywhere. If you

place the screen at *l*, it will receive, with the rays that come to a focus there, rays that have their focus at *F*.

In the eye the iris acts as the diaphragm or stop to the crystalline lens which is behind it, as was indicated in Fig. 139. Ordinarily, by means of this stop, the rays pass through only the central part of the lens.

330. Chromatic Aberration.—Another difficulty attending the operation of a common lens is what is termed *chromatic aberration*. Every ray of white light consists of a mixture of rays of seven different colors. Some of these colors are more easily refracted than others, and therefore on passing through a lens will come to a focus sooner. This of course is apt to make some confusion in the color and the distinctness of objects, when seen through a single lens, or through several if they are alike.

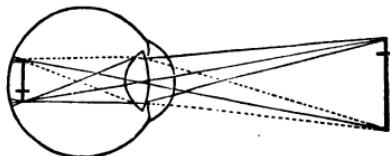
The difficulty has been remedied, and it is said that the hint of the remedy was taken from the arrangement of the eye. At any rate, the defect is avoided by having lenses made of different materials, just as is the case in the eye. Thus if two lenses be used, one of which is made of flint and the other of common glass, the difficulty disappears. In the eye it is perfectly avoided by the passage of the rays through so many different materials, before they reach the retina.

There is also an arrangement in the eye by which it adapts itself to different distances in looking at objects. If we look through a telescope at a near object, and then turn it towards one at a distance, we can not see the latter distinctly until we adjust the lenses to suit the distance. But in the eye how quickly the adjustment is made! It is done, ordinarily, without any conscious effort on our part. We look at an object at a few inches distance, and in an instant turn the eye and see an object afar off with almost equal distinctness. There has been much discussion in regard to the means by which this adjustment is effected, but the probability is that, as the lens is very elastic, it is kept in a state of tension by the elasticity of the suspensory ligament, and consequently is somewhat flattened. Now, if the ciliary

muscle contracts, it will draw the ligaments away from the lens, or diminish the elastic tension on the lens. The lens, consequently, will become more convex, but will return to its former shape, when the ciliary muscle ceases to contract.

331. Difficulty in the Near-sighted.—In some cases this power of adjustment is counteracted by defect in the structure of the eye. Thus, in the *near-sighted*, either the cornea or the crystalline lens, or both, are too convex; or, the crystalline lens is too far from the retina. The result is, that the rays of light coming from a distant object come to a focus before they reach the retina, as represented in Fig. 148. All objects, therefore, are seen indis-

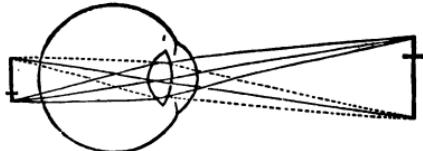
FIG. 148.



tinctly except those which are brought near to the eye. This defect is remedied by the use of a concave lens, which counteracts the effect of the too highly refractive power of the eye by making the rays divergent, instead of parallel, before entering the eye.

332. The Far-sighted.—In the far-sighted the difficulty is of an opposite character. The refractive power

FIG. 149.



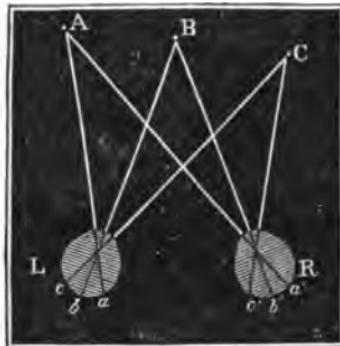
of the eye is too feeble. This is owing either to too little convexity of the cornea or of the crystalline lens, or of

both; or, to too great nearness of the crystalline lens to the retina. In this case the rays coming from a near object do not come to a focus soon enough. The focus of the rays coming from any point of the object is behind the retina, as seen in Fig. 149, in which the rays from two points are represented as prolonged till they meet. This defect is palliated by the use of convex glasses.

333. Correspondence of Action between the two Eyes.—It is an interesting and wonderful fact, that as we look at an object with both eyes, although there are two images formed, and therefore two impressions carried to the brain by the two nerves, yet but a single impression is produced in the mind. To produce this it is manifest that there must be a very exact correspondence in the two eyes as optical instruments. The two images must be similar, and must be formed on corresponding parts of the retina in both eyes.

Thus, if there be a range of objects, as at A, B, C, in Fig. 150, the impression of each will be a single one in the mind,

FIG. 150.



because the picture of each of these objects is on the same part of the retina in both eyes, *a*, *b*, *c*, and *a'*, *b'*, *c'*. But if you press with your finger one of the eyes a little out of its place, all these objects will appear double, because their images will occupy different parts of the retina in the two eyes.

334. The Two Images of an Object in the Two Eyes not Exactly Alike.—While it is necessary to single vision when both eyes are used, that the image of the object should occupy corresponding portions of the retina in the two eyes, it is not true that these two images are exactly alike. You can verify this by a simple experiment. If you hold a book before your eyes, with its back towards you and in a vertical direction, you see the back of the book and its sides at once, as a single object. If now, still holding the book in the same position, you shut one eye, you see but one side of the cover of the book—that one which is on the same side with the open eye. And so with the other eye. The plain inference is, that when you look at the book with both eyes, the image formed in the right eye is composed of the back of the book and the cover of the right side, while the image in the left eye is composed of the back of the book and the cover of the left side. From these two distinct images, two distinct impressions are sent to the brain; and yet but a single impression is recognized there by the mind, for the book is seen as a single object. This single impression must, therefore, result in some way from a mingling of the two impressions transmitted along the two optic nerves.

The statements in the last paragraph are beautifully illustrated by the instrument contrived by Professor Wheatstone, which he calls the stereoscope. In using this instrument, you look at two pictures of the same object with the two eyes, and yet you see but one thing—that is, but one impression is produced in the mind, although two different pictures are made in the two eyes, and of course two different impressions are conveyed to the brain.

Thus, the two representations of a dog, seen in Fig. 151, are seen in the instrument as a single dog. You observe that they are shaded differently. They are representations of the two pictures, which a dog in this position would make on the retina in both of the eyes of a person looking at him. When you look at them in the instrument, the single dog that you see stands out more than either of the

two representations, as seen when they are not in the instrument. The reason is obvious. In the two images formed in the eyes, as you look into the instrument, are all the lines of light and shade which you would see in looking

FIG. 151.



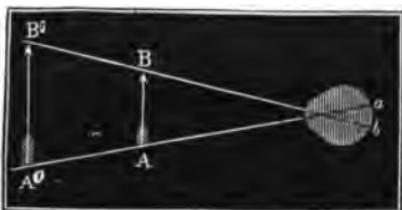
at a real dog with both eyes; while either one of these representations contains only a part of these lines.

335. Rude Imitation of the Stereoscope.—You can imitate in some good degree the effect of the stereoscope, by placing the end of a small book between these figures, and letting the other end rest against the nose and forehead, thus separating the eyes from each other. If now you look intently at the two figures, you will in a few moments find them approximate each other, till at length they mingle together, and you will see but a single dog, standing out like a statue.

336. Visual Angle.—Let us look now at the means by which we gain the experience that is necessary to correct vision. One means is the appreciation of the space occupied by objects in the field of vision. This is measured by what is termed the *visual angle*—that is, the angle which is formed by two lines coming from the extremities of an ob-

ject, and meeting in the eye, as represented in Fig. 152. In this way we get the idea of magnitude.

FIG. 152.



But it is manifest that it alone can not give us this idea correctly. It would do so, if all objects were at equal distances from the eye. But if they are at different distances, something evidently must be known of those distances, to estimate the magnitude of the objects by the visual angle, which they subtend. The arrow at A B will appear just as large as the larger one at A' B', because it will occupy the same space $a b$ on the retina, and subtend the same angle. But if it is known that the one is nearer to you than the other, allowance is made for this in the estimation of the size.

The hand, held up to keep the rays of the sun from the eyes, would look as large as the sun itself, if one did not know how near it is; and the sun and moon appear to us to have about the same magnitude, because we do not fully realize the fact that the sun is ninety-two millions of miles from us, while the moon is only two hundred and forty thousand.

337. Distance of Objects Estimated by their Distinctness.—Another means which we use in getting a correct idea of objects by vision, is the degree of distinctness in their lines, and shadows, and colors. The fact is learned very early by the child, that the nearer objects are, the greater is their distinctness; and he makes use of this fact continually in estimating both their distance and their magnitude. By this means, however, he estimates the latter less directly than he does the former.

He makes use of his notion of its distance gained, by its degree of distinctness. Many mistakes are made in the use of this means of judging the distance of objects. Thus, a very bright light will often appear to be nearer than one that is less bright. When the atmosphere is very clear, mountains and other objects appear nearer to us than they do when the atmosphere is thick and hazy.

338. Size of Objects Estimated by Comparison.—Another means of making a correct estimate of the distance and magnitude of objects is, comparison with other objects which are familiar to us. Thus, we get our ideas of the size of animals from objects in their neighborhood. The artist makes use of this means of communicating ideas of size. Figures of men are placed near large buildings for this purpose. A notion of the great size of the elephant is given by placing his keeper at his side. We are not ordinarily aware how dependent we are upon such comparisons, in estimating the magnitude of objects. For example, a person upon a giddy height suddenly turned his eye upon some huts below at a river's side; they appeared to be dog-kennels, till a man issued from the door of one of them, and thus, by affording a means of comparison, dispelled the illusion.

339. All Images on the Retina do not Produce Impressions in the Mind.—When it is said that images of objects are formed upon the retina, and that impressions are transmitted from *them* to the brain, this is far from stating all that is true on this point. Many of the images pictured upon the retina do not transmit impressions to the mind. The sensation of seeing is, therefore, in relation to them incomplete—only the beginning of the process is effected.

This can be verified by a simple experiment. If you hold a finger near the eyes (at some ten or twelve inches from them), and a finger of the other hand at a greater distance, but in the same direction, and then look at the near finger, you will perceive that the other finger appears double. So, on the other hand, if you look at the distant finger, the

near one appears double. The reason of this can be made clear to you by Fig. 153. The two eyes, L and R, being directed so that their axes converge on the object A, the middle points of the two images correspond with the middle points of the retina in the two eyes, *a* and *a*.

The images thus corresponding in their place on the retina, the impressions carried from them by the two optic nerves to the brain correspond also, and so the vision is single. But the image of the object B is formed in the two eyes, in parts of the retina that do not correspond, *b* and *b*. They are both on the *inside* of the middle points, *a a*; that is, towards the nose; whereas the outward part of the retina in one eye corresponds with the inward part in the other eye, and *vice versa*.

340. The "Blind Spot."—The sensibility of the different parts of the retina to light varies greatly. The point of entrance of the optic nerve is not sensitive to light, as may be proved by a very simple experiment. Close the left eye, and look steadily with the right at the letter A on the page, held at a distance ten or twelve inches.

A

B

The letter B will be seen quite plainly, as well as the letter A. Now, move the book slowly toward the eye, which must be kept steadily fixed upon the letter A. At a certain point the letter B will disappear, but as the book is brought still closer it will again come into view. This results from the fact that, in the first position of the book, the image of the letter B falls between that of the letter A and the entrance of the optic nerve; while, in the second

FIG. 153.



position, it falls on the entrance of the optic nerve itself; and in the third, inside that point. So long as the image of the letter rests upon the entrance of the optic nerve it is not perceived, and hence this region of the retina is called the *blind spot*.

341. Defense of the Eye.—The means by which so delicate an organ as the eye is protected from injury, are worthy of notice. Observe first its situation. Parapets of bone surround it, and receive most of the blows that come upon that part of the face. Above is the strong arch of bone, forming the lower part of the forehead. Then there are the cheek bones, and the bones of the nose. Thus, walled in, in all directions, by these prominences, the eye is seldom hurt, except by a direct thrust.

And besides being thus protected by surrounding bones, it reposes upon a soft cushion of fat, which yields, if the eye be pushed backward by violence. Indeed it is pushed backward effectually by the muscle that closes the eyelids whenever an impending blow is anticipated, and it is thus sunk farther back in its cushioned recess, amid the projecting parapets, and of course receives less of the force of the blow than it otherwise would. This muscle, also, by its instantaneous action, prevents many light particles from flying into the eye. Such particles are also often prevented from entering the eye, by being intercepted by the eyelashes.

The *eyebrow*, besides being an ornament, protects the eye from harm, by preventing the salt perspiration from running down into the eye, and irritating it. It acts as a thatched roof, projecting from the arch over the eye, and letting the perspiration from the forehead evaporate from it. The *eyelashes* also serve to keep the perspiration of the eyelids from entering the eye.

The structure of the *eyelids* is such, that the freest motion is allowed, while they afford by their firmness considerable protection to the organ. They derive their firmness from a fibrous cartilage, which makes the body of each lid. You can readily see that this cartilage, making an even

pressure on the surface of the eye, must often prove an effectual defense against direct thrusts. If the weapon hit this cartilage, it acts as a firm shield, to ward off the blow from the eye behind it.

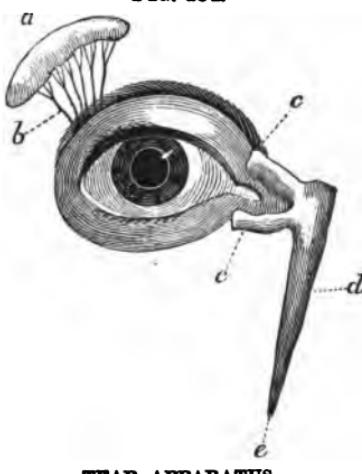
And even that part of the lid which is intended by its laxness to allow free motion to the lid, the skin, is often an effectual defense. If an impending blow be seen, and the eye be instantaneously and forcibly shut, the wrinkled skin forms a soft cushion over the eye, and thus not only covers it up, but serves materially to deaden the force of the blow.

342. Tear Apparatus.—The tear apparatus affords the eye material protection. The bland tears keep the organ properly lubricated, so that its constant motions occasion no irritation. And if any thing gets into the eye, the tears are manufactured abundantly, for the purpose of washing out the intruding substance. Fishes have no need of a tear apparatus, as their eyes are washed constantly by the water in which they live.

In Fig. 154 is represented the tear apparatus. The tears are secreted by a small gland, called the *lachrymal gland*, situated at *a*, in the orbit under the arch of the forehead, and near the outer angle of the eye. At *b* are the ducts which empty the tears in upon the surface of the eye on the inside of the upper lid.

By the constant motions of the organs the tears are diffused over its whole surface, and thus continually wash the eye. The arrangement for carrying off the fluid is this. It flows through a tube, *d*, *e*, into the nose. This tube has

FIG. 154.



TEAR APPARATUS.

at its beginning in the eye two branches, *c*, *c*, which open on the edges of the two lids at the inner corner of the eye. These open mouths, that drink up the tears as they flow to them, you can very readily see. The drain of the eye, which thus conveys the lachrymal fluid to the nose, is ordinarily capable of taking care of all the tears made by the gland.

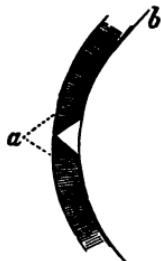
But when an uncommon amount is made, as in weeping, it cannot receive all the tears, and they therefore overflow their banks, the edges of the eyelids. And sometimes there is a constant overflow from obstruction of the drain by disease. The continual weeping of the eye, when this obstruction exists, will give you some idea of the amount of fluid which the lachrymal glands make.

343. Oiling the Eyelashes.—Along on the edge of each eyelid are some very small glands which secrete an oily substance. This serves two purposes. It oils the eyelashes, and also prevents the tears, when they are only in ordinary quantity, from being diffused over the edges of the eyelids in the constant motions of the eye.

This exceedingly small quantity of oily substance suffices to keep the tears in the eye where they are needed. There is also a curious provision for directing the tears to the

mouths of the ducts when the lids are closed. When brought together their edges unite in such a manner as to form with the surface of the eye a triangular channel for the tears to run in. This is made clear by the diagram in Fig. 155, in which the line *b* represents the surface of the eye, and *a* the edges of the lids, showing a section of the canal between them.

FIG. 155.



344. Nictitating Membrane in the Eyes of Birds.—We had intended

to notice some of the peculiarities of the eyes of different classes of animals. We will, however, notice but one—the *nictitating membrane* in the eyes of birds. When not in use it is gathered up in the inner corner of the eye. When

it is stretched over the organ we see that it is a thin translucent membrane. It is very elastic, so that as soon as the muscles sweep it quickly over the eye, it flies back at once to the corner where it is so snugly folded. In Fig. 156 it is represented as half way over the front of the eye. In Fig. 157 are seen the curiously arranged muscles that move it. One of the muscles, *g*, arises from the ball of the eye at its upper part, and running back, forms the trunk of the optic nerve, a tendon with a loop, through which the tendon of the other muscle, *p*, works.

This muscle arises from the lower part of the ball of the eye, opposite to the origin of the first muscle. Its tendon, *t*, is fastened into the edge of the nictitating membrane. It acts through the loop as a pulley, and you can see that the muscle, *g*, assists it materially in effecting the very quick motions of the membrane.

FIG. 156.

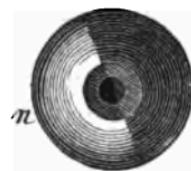
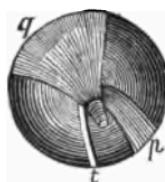


FIG. 157.



CHAPTER XVI.

HYGIENE.

AFTER having considered the construction of the machinery of the human system and the uses which the mind makes of it, one naturally inquires what the conditions are on which depend the full development of this complicated machinery and its daily repair?

345. Sources of our Knowledge of Hygiene. —The principles and rules of Hygiene are to be learned

from two sources. 1. They are to be learned from Physiology. As we observe the functions of the different organs, we can learn what those circumstances are which favor their due performance, and what those are which interfere with it. 2. They are to be learned, also, by observing the effects of those agencies which are known to interfere with the functions and to produce disease.

An exemplification of these two modes of learning the principles of Hygiene in relation to a single point will suffice. The study of the physiology of the chest shows us that nature has, in the construction of its framework, especially provided for giving ample room to the lungs; and so we deduce a law of Hygiene, that the chest should not in any way suffer compression. This is the first mode. But the same law can be deduced by the second mode, that is, by observing the results of compression of the chest.

Rules of hygiene generally have but little practical influence, unless the physiological facts upon which they are based are understood. Although the evil effects of their violation may be vividly portrayed, and even illustrated, as in the case of the chest, by engravings, the impression upon the mind is by no means so thorough and practical, as when the same lesson is enforced by a clear knowledge of the functions and arrangements of the organs and the conditions necessary to their healthy action. Physiology, therefore, should be studied as preparatory to a proper appreciation of Hygiene.

Not only is a knowledge of Physiology essential to a proper appreciation of the rules of Hygiene, but in many cases they cannot be fully understood in their *varied* application without such a knowledge. With the very partial and superficial knowledge of Physiology that is usually communicated with Hygiene, these rules are for the most part merely arbitrary. And just so far as the principles on which they are based are not understood, is there a liability to mistake their application.

In considering the subject of hygiene, the natural division of Physiology should be kept in mind. There is a

hygiene relating to the *construction* of the machinery of the body, and there is also a hygiene relating to the *uses* of this machinery. Besides, each organ has, to a certain extent, its own hygiene. And yet, as all the organs are more or less connected in sympathetic action, there is a general hygiene of the system.

346. Hygiene of Digestion.—Many of the points in the hygiene of the *digestive* organs have been already noticed in the physiology of digestion. Nothing more is needed in addition to what is said there of the importance of the thorough mastication of food, and of its having a due amount of saliva mingled with it; of the evils resulting from eating too fast, from eating between meals, and from eating a great variety of food; and of the influence of exercise upon the process of digestion. There are some other points, however, that remain to be noticed.

347. Quantity of Food to be Eaten.—No very precise rules can be given as to the quantity of food that is proper to be eaten. But a consideration of the physiological principles of digestion suggests rules that are sufficiently definite for practical purposes. There must be such an amount of food as will furnish sufficient chyle to keep the blood, the building material of the body, in proper quantity. The question arises, how shall we know what amount of food is requisite for this purpose.

Fortunately, the want of the system and its supply are commonly quite accurately indicated by the sensations. The proper hygienic rule then on this point is, that we should cease to eat when the sensations created by the want of the system are removed—that is, when the hunger is appeased, and the accompanying feeling of discomfort is succeeded by a feeling of agreeable ease.

348. Mistakes as to Quantity of Food.—But there are mistakes often made in regard to these sensations. They may be prevented from making a true report. Thus, when eating is done too rapidly, more food than is needed may be introduced into the stomach before the sensation of ease and satisfaction is experienced. It is only when

suitable time is given to mastication, and the food is rather gradually introduced, that this sensation indicates the proper limit of eating.

Again, there is a very common mistake in regarding the feeling of fulness instead of the sensation alluded to, as indicating the time for ceasing to eat. Those who adopt this false rule generally make the stomach bear as much as it can without absolute discomfort, and many daily overreach this point. The result is, that this organ soon gives out under this daily overworking; or, if the stomach be a strong one, an injurious repletion is produced in the system.

Too little food is sometimes taken. Poverty is commonly the cause. But sometimes it arises from false notions; as, for example, the notion that the quantity of food should be regulated by weight, or the more common notion, that we should rise from a meal with some appetite remaining. The result is, that there is not a sufficient supply of chyle to meet the wants of the system. The wear and tear create a demand which is greater than the supply, and the body therefore loses its fulness and its vigor.

349. Length of Intervals between Meals.—In determining the length of the intervals between the meals, we should have regard to the time required for the completion of the process of digestion, and to the wants of the system. Some articles are digested more rapidly than others, but it commonly requires from three to four hours to complete the digestion of a meal. When the system is in a state of action, its want of food, as indicated by its sensations, shows itself a little time after the completion of the process of digestion. The interval, then, between the meals should not vary much from five to six hours. If it be made longer, some degree of exhaustion results; and if it be less, disturbance of the digestive process may occur, from having the digestion of one meal begin before that of the previous one is fairly finished.

350. Regularity of Meals.—It is important that the meals should be eaten at regular periods from day to day. For the stomach, with its times of work and of

rest, naturally contracts regular habits, a disturbance of which is injurious. This obedience to habit in this organ is manifest whenever any change is made in the time of eating.

351. Quality of Food.—The question is often asked, whether such and such an article “is healthy,” as if there were essentially different degrees of suitableness in different articles of diet. So far as digestion is concerned, any article is healthy for any individual whose stomach can digest it without difficulty. An article may be perfectly healthy for one, and unhealthy for another. There are sometimes wide differences in this respect, owing to unaccountable peculiarities. But even in regard to ordinary differences, the question as to the propriety of any article of food is wholly an individual question.

Our food should be varied in the different seasons of the year to a greater extent than is common. In the warmer seasons it needs to be less stimulating, less heat-producing than in the colder seasons. The fruits, each in its season, should, in the warmer months, regularly form quite a large proportion of our food. If used thus, they will tend to prevent, rather than induce, the complaints peculiar to that portion of the year.

352. Influence of the Mind on Digestion.—The state of the mind has much influence on the digestive organs. This is sometimes strikingly exhibited in the loss of appetite on the sudden reception of bad news. It is also seen in the influence of continued sorrow upon the appetite and the digestion. It is not strange, then, that one of the prominent causes of dyspepsia is mental disturbance or depression. And a cheerful mind is very properly deemed to be essential to easy and thorough digestion.

353. Hygiene of Respiration.—In order to understand fully the hygiene of respiration, it must be borne in mind, that the great object of this function is to bring the air into all the minute air-cells of the lungs, that it may change the blood which is sent there for this purpose. Anything, then, which interferes with the free introduction

of the air into these cells is a palpable violation of the laws of health. And yet this interference is so commonly practised, that it is one of the prominent causes of disease.

354. Compression of the Chest.—This interference is effected in two ways. It is done, *first*, by mechanical compression of the chest. Although, as shown in the Chapter on the Respiration, there are special pains taken by the Framers of our bodies to provide, in the construction of the chest, for the free introduction of air into the lungs under all circumstances, this is often prevented by certain prevalent modes of dress.

It must be observed that in the arrangement of the chest, a free motion of its walls in the expansion of the lungs is contemplated. *The dress, therefore, should always be so loose as to admit of this free motion.* If it is not, the air is not freely admitted to all the air-cells, and therefore the blood is not so fully changed, as nature requires; and the health is impaired just in proportion to the degree in which the due expansion of the chest is prevented.

Compression not only produces disease in the lungs, but, by preventing these organs from effecting fully the requisite change in the blood, it impairs the quality and lessens the quantity of this building material, and thus diminishes the nutrition and the vigor of the system, and therefore renders it liable to a great variety of diseases, especially those of which debility is a prominent characteristic.

355. Importance of a Good Supply of Pure Air.—The free introduction of pure air into the lungs is interfered with, *secondly*, by cutting off its supply. As you learned in the Chapter on Respiration, the oxygen of the air is used up in large quantities by the lungs, and the carbonic acid gas thrown off takes its place. If, therefore, there be not sufficient provision for the supply of fresh relays of pure air, a mixture of air and carbonic acid gas will be introduced into the lungs at every breath, so that there will not be sufficient oxygen to effect thoroughly the change in the blood.

In this respect, therefore, the result is the same as when

too little air is admitted by reason of compression of the chest. A portion of the requisite quantity of pure air is shut out, in one case by diminishing the capacity of the chest, and in the other by having the lungs in part occupied by carbonic acid gas.

356. Bad Results of Defective Aeration
Seldom Appreciated.—The influence which this defective aeration of the blood, occasioned by these two causes, exerts upon the health, is seldom appreciated. For unless the deficiency be very great, no immediate obvious result is produced. But though the deficiency may be comparatively small, if it be continued from day to day for a long time, the aggregate result of this steady depressing influence is a serious one.

The destruction of health and of life that comes from this imperceptible agency in every community is vast in amount. But most persons seem to be insensible to this fact. They need a narrative of such a destruction of life as occurred in the Black Hole at Calcutta, to convince them that a considerable quantity of fresh air is required by every pair of lungs. And it is only by a description of an examination after death of some one who has been killed outright by extreme compression of the chest, that they can be made sensible of the need that the lungs have of the room that nature has given them. And even then the impression seems to be a momentary one.

If all the injury that is done by defective aeration of the blood could be visibly traced out, we should then realize the necessity of having just as many of the air-cells, those little chemical laboratories, as nature designed, and of keeping them well supplied with the fresh air which they require for the life-giving work that they perform.

357. Hygiene of the Circulation.—The hygiene of the circulation need not detain us long. The office of the organs of the circulation is to circulate the blood, the building material, everywhere. They never rest from their work. But they work more actively when the muscular system is in action than when it is at rest. As one lies in

bed, the circulation goes on steadily, but quietly. But on rising and moving about, the circulation becomes more active. Not only does the heart beat more quickly, but the capillaries in every part of the body increase their action. And, as more blood is carried to every part, there is more done everywhere. We see this in the skin, in the increase of the perspiration on exercise. When the muscular effort is very great, the excitement of the circulation is violent and tumultuous. The heart beats strongly and rapidly, and the flushed face shows how active is the circulation in its extreme vessels, the capillaries.

358. Exercise Necessary to Health.—The occasional excitement of active exercise is absolutely essential to the proper physical development. The body may sometimes, indeed, maintain its proper bulk in a continued state of muscular inaction; but its textures will not have the requisite strength and tone. That they may have these qualities, it is necessary that the blood be often pumped into their capillaries with the force that is given to the heart by active exercise.

It is not the muscles alone that are rendered stronger and firmer by exercise, but the same effect is produced in all the textures, the bones, the ligaments, the veins, the skin, &c. The great internal organs of the body are firmer, more fit to perform their duty, and less liable to disease, if the circulation in them is excited daily by this means. Active exercise makes the stomach digest better, the lungs perform the work of aerating the blood more thoroughly, and the brain serve the mind more easily and effectually; it therefore renders one less liable to dyspepsia, to consumption and other diseases of the lungs, and to apoplexy and other diseases of the brain and the nervous system.

But the activity of the circulation may be made so violent by exercise as to do some damage. Though its organs are capable of bearing much in this respect, there is some need of caution. Harm is undoubtedly often done in trials of strength when the effort is both violent and prolonged. Vigorous action answers fully the purpose of developing

power and firmness; but violent action is attended with some hazard.

359. Hygiene of Formation and Repair.—In considering the hygiene of *formation* and *repair*, it must be borne in mind that there is constant change everywhere in the system. Particles that have become useless in the textures are continually taken up and carried away in the veins or the lymphatics, and other particles are put in their places, being taken for this purpose from the blood in the capillaries. This change is going on during all the period of growth, as well as afterwards. The health and vigor of the textures, and therefore of the system as a whole, are dependent upon the proper performance of this constant process of removal and fresh supply.

There are two conditions necessary to the due performance of this process. The *first* is, that the blood, the universal material for building and repairing, shall be of good quality. This is secured when the digestive process, which furnishes the blood, is well performed, and the lungs and other organs, that purify the blood by discharging its refuse matter, are in good condition. The *second* condition is, that the blood shall be often quickened in its course through the organs by the excitement of exercise. This has been mentioned in speaking of the hygiene of the circulation.

360. Necessity of a Free Discharge of the Waste.—The necessity of having the waste matter that is brought back from all parts of the body in the venous blood, effectually discharged by the various organs designed for this purpose, requires a particular notice. The lungs, the skin, the liver, the kidneys, &c., must thoroughly evacuate this waste, or its retention will impair the quality of the blood, and thus interfere with the proper nutrition of the body, or, in other words, with the process of formation and repair. And the retention of this refuse in any considerable amount is immediately productive of disease.

The lungs, while they take in oxygen from the air, discharge carbonic acid gas, that part of the waste of which it is their duty to rid the system. If this carbon be retained,

the blood is impure in proportion to the degree of retention.

361. Functions of the Skin.—It is the duty of the skin to discharge some portion of the refuse of the system in the sensible and insensible perspiration. The skin is not a mere covering of the body, but it is also an active organ, performing very important functions. It continually discharges through its numberless pores a large quantity of matter.

Although this matter is mostly in an insensible form, if from inactivity of this organ it fail to be discharged, its retention renders the blood impure, and so does injury to the system. At least two pounds of matter are discharged from the skin in twenty-four hours. This being the case, it is not at all wonderful that activity of this organ should be so necessary to health, and that the suspension of its secretions should have so much influence in the production of disease.

362. Animal Heat.—In the Chapter on Respiration you learned that the heat of the body is produced by the change that takes place in the blood in the capillaries, as it receives the waste particles, and as the new are deposited in their places. This change makes a real combustion in every capillary. The more rapid therefore is the change the greater is the combustion, and of course, the greater is the heat. Hence comes the increased heat of exercise.

Exercise makes more wear and tear, and so disengages in the waste more carbon and hydrogen to unite with the increased amount of oxygen that comes in the quickly flowing blood to the capillaries; and just as in combustion that is attended with flame, the greater the amount of fuel the greater is the heat. We have a familiar example of the production of heat by exciting the circulation, in the expedient often resorted to by laborers for warming the hands, of striking them with a swinging motion upon the shoulders.

The amount of heat produced in the body depends also on the quality of the blood. The richer it is, the more oxygen it contains, and therefore, the brisker is the fire in the

capillaries, and the greater is the heat. You see then why it is that those who have a good state of the blood, and exercise much, maintain the heat of the system better, and so need less clothing than those whose blood is weak, and who exercise but little.

The heat of the body is maintained in all temperatures of the atmosphere very nearly at 98° Fahrenheit. This is, you observe, much above even the highest temperature that is agreeable to us. You see then that it is essential to the comfort of the body that it be giving off heat continually to the surrounding atmosphere. If the atmosphere be at 98°, the same temperature with the body, there is great discomfort, from the fact that the heat is given off too slowly.

It would not be parted with at all if the skin were not an active organ. It is by the evaporation of the perspiration thrown off by the skin that the extra heat is got rid of when the air is so hot. The temperature in which the body is generally most comfortable is about 70°. When the atmosphere goes below this, we need the ordinary expedients to prevent a too rapid escape of the heat from the body. The clothing and the heated air, with which we surround ourselves to guard against the cold, do not act by communicating heat to the body, but simply by retarding its escape.

Cold is a depressing agent, and exerts as such much influence in the production of disease. Statistics show this in a striking manner. The statistics of London, for example, prove that the mortality of a severe winter is much greater than that of a mild one. And this difference is found to be chiefly among the very young and very old, because in them the power of generating heat is feebler than in other classes.

The greater is this heat-producing power of the system, the better does the system resist the depressing influence of cold. All those means, therefore, which *promote the vigor of the body*, are the best of the safeguards to be used against this productive cause of disease and death. But, besides

thus fortifying the body internally against this depressing agent, we have the means of outer defence alluded to, in clothing and heated air. As there are many errors committed in using these, they require a more particular notice.

Clothing serves, as has been said, to shut in partially the heat which is generated in the body. Its amount and character should be regulated by two circumstances—the degree of the cold, and the amount of heat-generating power in the system. The vigorous require less clothing than the weak, because they have more of this power; so, also, the body needs less clothing when it is in exercise than when it is in a state of rest, because in exercise it generates more heat. And the same principles apply to *heated air*, for this is an outer covering for the body, interposed between it and the cold, like clothing, for the purpose of preventing the too rapid escape of the heat generated within.

These plain principles are violated in various ways. Many, from carelessness or from mistaken notions, are often unnecessarily exposed to the depressing influence of cold. They are not sufficiently aware of the necessity of guarding *so much more thoroughly against the cold when at rest than when exercising*. And then, on the other hand, they add to the effect by having too much clothing when in action, or when in a warm place. When they thus suffer first from too much heat, an after exposure to cold is exceedingly injurious.

The weak especially suffer from exposure to cold when the body is at rest, and therefore, they should take special pains to guard themselves against this depressing agent. Any attempt on their part to harden themselves, as it is expressed, by making use of as little clothing as the vigorous wear, particularly when the body is in a state of inaction, always does harm.

The very thin coverings so commonly seen on the feet of delicate females are palpably inconsistent with this rule of hygiene, and are in ridiculous contrast with the stout coverings considered necessary for the feet of vigorous men.

363. Cold Sometimes a Stimulant.—The depressing influence of cold sometimes produces a marked immediate effect. But this is not generally the case. Commonly no harm is apparently done at the time, and so little is thought of it. But if this influence be continued day after day, its effects accumulate and become established. The vigor of the system is more or less destroyed, and some local disease may make its appearance. The debilitating influence of cold is in this way a fruitful cause of disease, not only in the abodes of poverty, but even among those who have ample means of guarding against it.

Although cold is generally a depressing agent, it is often indirectly a stimulating one. It is so when, in consequence of its impression upon the skin, it excites what is termed a *reaction*. Several circumstances are necessary to this result.

1. There must be the power of reaction in the system. There may be so much debility that reaction can not be awakened.
2. If the system be in a state of rest, the application of cold must be temporary. A continuous application of it would be depressing, and would forbid reaction.
3. In an *active* state of the body, reaction may be produced even when the application is continuous. Thus the mere exercise of dressing may suffice to awaken reaction in a degree of temperature which would chill one through if he were sitting still.

364. Conditions on which Reaction Depends.—The system may be accustomed to react under the impression of cold in two ways. 1. By exercise in the open air in cold weather. Those who have but little outdoor exercise in cold weather, have but little power of reaction, and therefore feel the depressing influence of the cold whenever they are exposed to it. 2. By a judicious use of cold bathing. The object of cold bathing, aside from purposes of cleanliness, is to accustom the system to react under the influence of cold. It is only when reaction occurs under its use that it does good. It does positive harm when reaction does not occur; and the harm done in this way day after day, by depressing the vital powers, is sometimes at length ruinous to the health.

365. Cold Bathing.—There is a want of proper discrimination in many writers on hygiene in regard to cold bathing. It is a mistaken ultraism to say, as is often said, that the preservation of health requires that the whole body should be bathed every day in cold water. Neither cleanliness nor the other purpose mentioned ordinarily requires so frequent and thorough bathing as this. The water may be applied to only a part of the body at a time, and yet accomplish all that we wish. Indeed, some persons of delicate constitution can not bathe the whole surface at once with cold water. They may at first be able to apply it to only a small part of the body.

But they may, with the aid of friction, after a while come to apply it over a considerable portion of the surface, or perhaps over the whole. In some persons this extension of the limits of the bathing from day to day must be done very cautiously; and there is occasionally one that can not bear it at all over any considerable extent of surface. It is necessary for some, in accustoming themselves to cold bathing, to begin with using tepid water, making it from day to day a little colder.

The best time for cold bathing is commonly in the latter part of the forenoon, for the system is then in its most vigorous state, and is therefore best prepared to react. But in most persons reaction can be secured at the hour of rising, and this is the most convenient time for bathing. Few can use the cold bath with profit in the latter part of the day, for the powers of the system are then more or less exhausted, and full reaction is not easy. The soothing influence of the warm bath is appropriate at that time. There are many other points in regard to bathing that might be noticed, but space will not permit it.

Thus far we have spoken mostly of the hygiene of the body as a *structure*. But digestion, the circulation, &c, are engaged in constructing and repairing organs for the *use* of the mind. In this use, there is wear and tear, and hence is the necessity of seasons of rest, that the needed daily repair of the organs may be effectually done. The mind uses

the muscles and bones for motion, the various organs of the senses in gaining a knowledge of the world around, and the brain in thinking, willing and designing. Any of these organs may be overworked, and after a certain amount of work has been done, there needs to be an interval of rest for repair. The repair is going on continually, while the organs are at work; but it can not be done thoroughly without these intervals of rest. Most of the repairing is done in these periods. This simple statement suggests the principles of hygiene in regard to the uses which the mind makes of the organs of the body. These will now be developed briefly in regard to the muscles, the senses, and lastly the brain.

366. Exercise Necessary to the Development of both the Muscles and the other Organs.—There is a certain amount of muscular exercise which is essential to firm health. While no one can fall below this amount without impairing the healthy vigor, the laborer goes much beyond it without injury. There is a wide range, therefore, in the amounts of muscular exertion that are consistent with health.

The exercise of the muscles is necessary to their full development. When a limb fails to be used, as, for example, in palsy, the muscles become small and lose their firmness. When, on the other hand, the muscles of any part of the body are much used, they become more developed than others less used. For example, the labor of the blacksmith develops the muscles of his arms largely. The same thing is true of the muscles of the leg in the rope-dancer. It is only a general exercise of all the muscles of the body that develops them in all parts of the frame in their due proportion.

But muscular exercise is also necessary to the proper development of the other textures as well as the muscles. There is one illustration of this influence of exercise which deserves a particular notice, as it serves to prevent deformity. In the universal vigor and firmness of the textures which free exercise tends to produce, there is

ordinarily a precise equality between the two halves of the body: the muscles on the two sides act with equal power; the spinal column, the grand pillar of the trunk, is held between the muscles that bind its twenty-four bones together with great exactness, and there is a beautiful symmetry in the whole frame.

But when, from lack of exercise, there is want of firmness in the textures, this symmetry is apt to be lost during the development of the frame, and the spinal column is especially apt to become deformed.

367. Deformity of the Spine.—There are two immediate causes of this deformity, viz., irregular muscular action, and irregular pressure. Weakened muscles are prone to act irregularly; and structures that have lost their firmness, readily yield to any pressure that is laid upon them. When there is firmness of texture, irregularities of pressure are not apt to produce deformity, because the elasticity prevents the permanent influence of such pressure. The moment the pressure ceases, the elasticity of the part restores it to its usual shape. The firm regular action of the muscles also tends to the same result.

Thus, in the case of the spinal column, if the posture of the body be such that it is bent over to one side for some time, the moment that the posture is altered, the elastic cartilages resume their usual shape which has been temporarily changed by the unusual pressure, and the muscles also that lie along this pillar of bones bring them at once to their right position.

But if the cartilages have lost in some measure their elasticity and the muscles are weak, the righting up of the spinal column is not fully accomplished; and a succession of slight failures in this respect will, after a while, produce a permanent deformity in the direction of the most commonly assumed posture.

You can see all this exemplified if you observe the difference between males and females in regard to deformity of the spine. This deformity is exceedingly common among girls, while it is rare among lads. The simple reason is,

that lads have the invigorating influence of free out-door exercise. Too much influence is attributed to posture in producing this deformity. Posture is often spoken of as being the chief cause of it, and this view of the subject is illustrated extensively with cuts, showing how the deformity is occasioned.

If this were the correct view, there should be much less deformity among girls than among boys in our schools, for the former sit in a crooked posture much less than the latter do. So far as posture does have an influence, it is quite clear that the prim, fixed posture enjoined upon the girl has a tendency to produce deformity, by adding to one of the causes from which it proceeds, viz., the weakness of the muscles. A fixed uniform posture wearis the muscles, but variations of posture relieve them, and so prevent an exhaustion of their power.

The muscles of the back in the female are weakened, in common with the other muscles, not only by a want of stirring out-door exercise, but also by a special cause of weakness in their case. The tight dress of the girl prevents these muscles from having that free action which the loose dress of the boy permits. You can see this in the difference of movement in the two cases. In the boy, the spine is bent and twisted in all directions freely; but in the girl, both custom and the stiff tightness of the dress require a movement almost as if the spine were a single bone, instead of being made up of twenty-four bones. The muscles in her back, therefore, lose their power and fulness just as the unused muscles of a palsied limb do.

368. Exercise should be Varied and General.—Variety should be aimed at in the action of the muscles. A continuous action of any set of muscles is wearisome and painful. This is well exemplified in the punishment once much in vogue in schools, of making the offender hold a book out at arm's length for some time. In the management of the muscles of the voice, the weariness caused by continued sameness of action is often experienced. The monotonous speaker or reader tires out these

muscles much sooner than one who has great variety in his tones.

369. Gymnastics and Calisthenics.—A general exercise of all the muscles is essential both to symmetrical muscular development, and to the full attainment of the invigorating effects of exercise. Gymnastics and calisthenics are, in this respect, particularly beneficial. These are, however, no better than any other exercises that are so varied as to bring the muscles generally into action.

The varied exercises of walking, running, leaping, riding on horseback, dancing, and active sports, are quite as good; so also are the varied labors of the garden, if they be pursued with interest and pleasure. There is no especial benefit in the *extreme* variety of exercise sometimes aimed at in gymnastics. Variety that is sufficient to bring into general action the muscles of the body is all that is requisite.

Gymnastics and calisthenics should always be considered as subsidiary to the common exercises that have been mentioned, and should never be permitted to exclude them. When they are made to do this, a temporary benefit is reaped at the expense of a permanent injury. For after the novelty of the round of exercises has passed away, they are given up, and the common and now despised exercises are not apt to be resumed. Habits of inaction, therefore, are often confirmed, instead of being removed, by a systematic course of exercises under the high-sounding names of gymnastics and calisthenics.

370. Effect of too severe Exercise.—But there may be too much exercise. The toil of the laborer may be so severe and long-continued, that the reparative process in the intervals of rest is not competent to effect a full repair of the muscles. A gradual exhaustion of their power, therefore, results. Much harm is thus often done by severe unremitting toil. Especially is this the case when the excess of toil is exacted during the period of growth.

It is necessary that exercise should be agreeable in order

to produce its best effect on the system, on account of the genial excitement which then accompanies it. For this reason exercise should commonly not be solitary, and there should, if possible, be some object connected with it. If the observation of nature were made from the beginning of education as prominent as claimed in the Preface that it should be, there would be no lack of objects in the rambles in field and forest taken both for health and for the pursuit of science.

371. Hygiene of the Senses.—Substantially what has been said of the muscles may be said of the organs of the senses. They require intervals of rest for thorough repair. And they may be so overworked that complete reparation is rendered impossible, and their power be gradually exhausted. The office of the senses is to receive impressions from things around. Whatever gives an impression to any organ of sense may be regarded as a stimulus to it. If the stimulus be too great or too long continued, injury is done. This is very obvious in regard to the eyes. They are often injured by too much light. A word of caution is needed in regard to the production of near-sightedness. This is often caused in students and others by holding objects too near the eyes.

372. Necessity of Seasons of Rest to the Brain.—We come now to the hygiene of the brain. This is the great central organ or instrument of the mind, by which it receives the impressions made upon the senses, compares and arranges the knowledge thus gathered, and originates those impressions that are made by it upon the world around through the action of muscles. It is a very compound instrument. It needs, like the muscles, seasons of rest for the full repair of the wear and tear occasioned in its daily use.

It may be overworked, and then the repair will not be complete, and gradual exhaustion of its powers will result, occasioning disease in some form. A significant illustration of the importance of seasons of rest for repair in the case of the brain is furnished in the fact, that

insanity is not apt to result from mental disturbance, unless the subject of it fail to have his regular sleep. If he sleeps well, the work of repair is so well done in the brain in its nightly seasons of rest, that the disease, which might otherwise occur, is prevented.

With proper intervals of rest, the mind can perform a large amount of labor without injury to the brain and nervous system, if there be no undue excitement, and no worrying and depressing anxiety. This is shown in the length of life that so often accompanies the quiet but laborious pursuits of science, while, on the other hand, the excitement and anxiety of a life of business, especially as it is ordinarily pursued in this country, are not favorable to longevity.

373. Overworking the Brain.—It is especially important that the brain, during the period of its growth, should not be overworked. The reason is the same as that for the caution, so universally observed, in regard to putting too much labor upon the muscles of a young horse. And yet there is buoyant activity in the child, which is disposed to show itself in the operations of the brain as readily as in the action of the muscles. If this activity be turned into proper channels, and be not too much stimulated, no injury will be done to the delicate textures of the brain.

Although much is said of the danger of over-stimulating the brain of the child, the difficulty does not so much lie here, as in the manner in which the mind is led to act. There is commonly too much of mere drudgery, and of storing the mind with unintelligible, and therefore uninteresting matters. The mind, accordingly, is dissatisfied and wearied. The tedium of the labor exhausts, and so the brain is essentially impaired. When early education shall become in all respects what it ought to be, greater real acquisitions will be made without any injury to the growing brain.

374. Influence of Quiet Cheerfulness.—It is well known that undue mental excitement and the depres-

sion of anxiety are together apt to produce insanity. Though they generally stop short of this result, they always injure the health and shorten life. A firm and cheerful mind is favorable to longevity, but the anxious and fretting are seldom, if ever, long-lived.

375. *The Passions.*—As the passions must have much influence upon the action of the mind, and therefore upon the state of the brain and nervous system, the proper regulation of them is essential to health and longevity. Much of the positive disease of the brain, and of the general nervous derangement so common among the educated and refined, comes from the bad management of the passions:

376. *Alcoholic Stimulants.*—There are certain articles in common use in the community, which produce so deleterious an influence upon the system, that they demand a more extended notice than can be given them in this chapter. Reference is made to alcohol and tobacco. They act chiefly upon the brain and nervous system, the former as a stimulant, and the latter as a sedative. The use of opium is so limited compared with these, that it will not be dwelt upon, especially as it is never defended.

No fact is more thoroughly demonstrated than that the system has no need of alcoholic stimulants while in a state of health. So far then as we look at mere necessity, these articles are to be considered simply as medicines, required only in diseased conditions. But it is said by some that they can be used in small quantities without injury to health. This cannot be claimed with any shadow of reason, except with relation to very small quantities.

Entire abstinence is at least safe, and there are so many other things supplied by a bounteous Providence to gratify the taste and the appetite, that we can easily forego the use of alcoholic stimulants; and we ought to be willing to do so, if the good of others require it. The common use of these articles as beverages is one of the most prolific of the sources of disease; and it is a significant fact, that the

very moderate use, claimed by some to be innocuous, has a strong tendency to pass into a larger use, even so large that its deleterious influence upon health is palpable.

377. Tobacco an Active Poison.—The evidence is quite as clear in relation to the injurious effects of tobacco. This has sometimes been erroneously termed a stimulant. The error arises from the well-known discomfort of the habitual user of it when he is deprived of the use of this drug. This discomfort has a **depressing influence**, and when his system is brought again under the influence of tobacco the depression is removed, not by any direct stimulating effect, but by the relief given to the uncomfortable sensations.

Tobacco is really one of the purest sedatives we have. It depresses vital action. It acts chiefly upon the nervous system, and therefore has a strong tendency to produce nervous diseases. While it is injurious to all, it is especially so to those who have a low vital action, and are disposed to nervous complaints.

Tobacco is so active a poison that extreme caution is required whenever it is administered, as it sometimes is, as a medicine. The effects of even a small amount of it upon one that is unaccustomed to its use are of the most decisive character. And that must be an exceedingly artificial condition of the system, in which, by continued use of this drug, large amounts come to be borne with little apparent effect.

The evidence of the deleterious influence of tobacco upon the system is as unequivocal as that in regard to the influence of opium, and wonderfully strong is that slavery to appetite that makes one persist in the use of this drug in spite of such evidence.

378. Coffee and Tea.—Coffee and tea are often included in the same category with alcohol and tobacco. Granting all that is claimed in regard to the injurious effects of these articles, it is preposterous to class them with such poisons. The evidence in regard to them is conflicting, and all that is settled as yet is, that in some persons

they exert a bad influence upon the nervous system. If this should be found to be true of a very large proportion of all who use them, the evidence would be conclusive against the propriety of their use as common beverages. But as yet this has by no means been proved to be true.

379. Poisonous Emanations.—There are certain poisonous emanations, to which the human system is often subjected, that are largely destructive of health and life. They arise from decomposing filth of various kinds. Besides predisposing the system to the action of contagious and epidemic causes of disease, they also of themselves create disease. It is these emanations that render the close air of a crowded city, especially in its narrow lanes, so impure and fairly poisonous. And this impurity of the air is one of the chief causes of the difference in disease and mortality between the city and the country. The difference is greater than is generally supposed.

It has been found by statistics in England, that there are 24 per cent more deaths from consumption, and 55 per cent more deaths from typhus, in cities than in the rural districts, and the mortality from the diseases of childhood is twice as great in the city as in the country. In what way these emanations act we know not. But, although much is to be attributed to a mere want of ventilation, that is, to a lack of oxygen, there is no question that these emanations often act as positive poisons to the system.

380. General View of the Causes of Disease.—In developing the principles of hygiene, we have noticed many of the prominent causes of ill health and disease. They are chiefly these: 1. A disregard in various ways of the rules relating to the digestive process. 2. Compression of the chest, especially during the period of growth. 3. Deficiency in the supply of pure air to the lungs. 4. Failure to guard properly against the influence of cold and heat, chiefly the former. 5. A lack of active exercise in the open air. 6. Overworking the muscles. 7. Errors in the management of the moral and intellectual powers. 8. The

influence of such articles as alcohol and tobacco. 9. Emanations from decomposing filth.

It is well thus to look at these causes grouped together, endeavoring to give to each its due prominence. For various and exclusive views are often taken on this subject. Quite commonly some of these causes are kept entirely out of view, while others are strongly pressed upon our attention. Disease is generally a very *compound result*, produced by a concurrence of several of these causes, and sometimes even of all of them.

These causes of disease, it will be observed, are more or less under our control. Some of them are entirely so. A knowledge of their operation, and an earnest endeavor to remove them, would, therefore, vastly diminish the amount of ill health and disease.

381. Our Control over the Causes of Disease.

—It is true that there are some other causes of disease, of which we know but little, and over which we have little or no control. Such are the causes of various contagious and epidemic diseases. But these really produce a much less amount of disease than the causes which have been mentioned. Their action is occasional, and confined to localities; not continual, and in all places. And besides, they may to a great extent be shorn of their power, by guarding against those causes of disease which are more or less under our control. It is those who neglect to do this that commonly become most readily the victims of contagions and epidemics.

382. Preventive and Curative Measures.—

There is much interest in the community in regard to the cure of disease, but there is a blind indifference to its prevention. *And yet vastly more can be done in the diminution of disease by preventive than by curative measures.* The ravages of consumption, for example, can undoubtedly be greatly lessened by preventing the operation of its principal causes; and yet what is said about these causes is little heeded, and the public attention is engrossed with the delusions of consumption-curers.

It is emphatically true of this malady, that multitudes more can be saved by preventive measures than by curative ones. Against no disease can hygiene achieve greater victories. The neglect to use preventive measures against this and other diseases arises chiefly from the ignorance of the principles on which these measures are based. The prevalent indifference, therefore, to this subject can never be fully removed, till the general introduction of Physiology as a study into our schools shall make these principles familiar to the mass of the community.

PART SECOND.

CHAPTER XVII.

CONNECTION OF THE MIND AND THE BODY.

THE Nervous System is to the mind the grand means of communication with the world of material and immaterial things around it.

This communication is maintained through organs subordinate to the nervous system. And you have seen that through the senses all knowledge of external things is communicated to the mind, where it is used as the material of thought and feeling; while, on the other hand, through the muscles the mind produces all its impressions upon external things.

Let us now look more thoroughly into the connection which the nervous system establishes between the mind and the body, and observe some of the higher and more intricate phenomena which result from it.

383. *The Brain the Organ of the Mind.*—The brain is the organ of the mind. In this life there can be no mental manifestations except through the agency of this organ. The mind and the brain always act together as one thing. This is manifest in regard to motion and sensation. It is equally true of thought. The mind can think and excite motion in the muscles only through the brain. The proofs of this are various and abundant.

If a man by a blow upon his head have a portion of the skull driven in upon the brain, so as to press upon it considerably, all sensation and power of motion are suspended.

His mental connection with the world around him is completely cut off. And furthermore, all mental action is arrested. The mind, thus shut in from the world around by the suspension of sensation, does not go on to act independently of the compressed brain.

It may be remarked, that this degree of the suspension of the mental functions depends upon the degree of effect produced upon the brain. If, for example, in the case of injury, the pressure of the bone driven in upon the brain be not very great, the suspension will be partial; but if the pressure be considerable the suspension will be complete.

384. *Insanity a Disease of the Organization.*—Insanity is always the result of disease in the organization. This is so even when it is produced by moral causes acting directly upon the mind. The insanity in such a case is an *indirect* effect—the organization affected by the mind is thrown into a diseased state and reacts upon the mind, influencing its manifestations.

If the mind thus acted upon were a spirit, separated from the body, the result would be merely the feelings, which the motives applied would *naturally* produce, and not the unnatural feelings of insanity. It is not strictly proper, then, to speak of a “mind diseased.”

Let it not be understood that mental derangement in every case is to be attributed to disease that leaves such palpable traces that the dissecting knife would reveal it if death were to take place. There are diseased operations of the body that are hidden from our view—so hidden, that they not only leave no traces, but often develop no characteristic bodily symptoms.

385. *Situation of the Brain.*—Observe for a moment the situation and the immediate connections of the brain, the organ of the mind. It is fitly placed at the summit of the structure, inclosed by that noble dome which was described in the Chapter on the Bones. And then observe that, in its immediate neighborhood, are the organs of four of the senses, sending their messages continually to the mind. Especially notice that under the jutting arches of

the front of the dome are the ever-moving eyes, looking out from their elevated place of observation; and at the sides of the base of the dome are the halls of audience, ever open and ready to transmit the messages that come to the soul through the vibrations of the air. And there, too, in the very front of this habitation of the mind is the face, indicating by the delicate, quickly changing play of its muscles the thoughts that are at work within. And lastly, there is the mouth, the outlet for the voice, the chief agent of the outward manifestations of the mind.

Here then are clustered together in this small space, in the immediate neighborhood of the mind's habitation, its principal instruments of communication with the world around. When we are listening to eloquence, whether it be in the public assembly, or in the social circle, or in the more private intercourse of friendship, and observe, as the rich tones proceed from the mouth, the elevated and changeful expressions of the countenance, we are impressed with the idea that, if it be the mind which constitutes the image of God in man, the face of man thus situated in the front of the mind's habitation is the fitting outward emblem of that image.

386. Rapidity of Communication between the Mind and Body.—It is interesting to observe how exceedingly rapid are the communications of the mind with the different parts of the body. Notice what the process is, or rather what the processes are, when you withdraw your hand from any thing that hurts it, as heat for example. An impression is produced upon the expanded nerve in the part—this impression is sent along the nervous tubuli to the brain—the mind there receives the impression—the mind in return communicates an impression to the brain—this impression goes by another set of nervous tubuli to the muscles—they act, and the hand is withdrawn. If it took as long to do all this as it has to describe it, the hand would be very thoroughly burned before it is drawn away.

387. Skill in the Use of the Muscles.—The use which the mind makes of all the machinery of the senses

and of the organs of locomotion does not come to it at the outset. It comes by training, and in some cases by very long training. The child at first uses its muscles bunglingly. It does not see or hear skillfully. It knows nothing at first of the colors, or shapes, or distances of objects. It knows nothing of the direction or distance of sounds. It has all these things to learn. And for this purpose the organs of sense and the muscles are put into exercise at once, and the child begins its long process of learning on the day of its birth.

Few have any conception of the amount of knowledge which is acquired in the first of the child's life. Not only is he born with absolutely no knowledge of the world of things around him, but he has no skill in the use of the instruments, the muscles and the senses, by which he is to obtain his knowledge. These give him at first no very definite information; but by the constant exercise of them, and by comparisons between the reports of the different senses, he soon adds rapidly to his stock of knowledge, and becomes skillful in the use of his means of gathering it.

388. Skill in the Use of the Senses and the Muscles.—Skill in the use of the muscles varies much in different individuals. It is wonderful in the juggler, the rope dancer, the skillful player on a musical instrument, and the accomplished singer. You will have some conception of what education can do for the muscles, if you contrast the awkward balancing of the child in walking with the agile and delicate balancings of the rope-dancer, or the aimless and uncouth movements of the infant's hands with the rapid and varied execution of the player on an instrument, or the monotonous and coarse sounds uttered in a child's first attempts at singing with the varied melody of a skillful singer.

The senses are educated as well as the muscles. As you see an infant reaching out his little hands awkwardly with his unskilled muscles towards an object, it is manifest that he knows not at what distance the object is from him, and that he does not readily adjust his eyes to its distance, so as to see it clearly.

He after a while by practice acquires the power of doing this. The same may be said of hearing. The little muscles described to you as so nicely adjusting the eye for seeing at different distances, and the ear for hearing various notes of sound, require training, just as the muscles do with which we walk or talk.

389. The Senses and the Muscles Mutual Teachers.—The senses and the muscles are mutual teachers in the education here described. Thus, in singing, the accuracy of the sense of hearing in estimating sounds is acquired through the action of the muscles of the voice while the ear is listening. And on the other hand, skill in executing sounds is acquired by these muscles under the tuition of the ear. The dependence of the senses upon the muscles is not absolute, however, as is that of the muscles upon the senses.

The ear can be trained in the accurate appreciation of sounds without any corresponding exercise of the muscles of the voice, though the two processes are ordinarily to a greater or less extent connected, and are corrective of each other. But even when the ear is trained without any aid from the muscles of the voice, the training is in some measure a training of muscles.

For there are certain little muscles that regulate the tension of the drum of the ear, which undoubtedly go through a process of training when we are learning to distinguish accurately between different notes of sound. While the dependence of the senses upon the muscles is thus a partial one, the dependence of the muscles upon the senses is, on the other hand, complete.

Although the muscles have a sense of their own, a muscular sense, as Bell calls it, this is not adequate to be their sole guide in action, but it serves as a mere auxiliary in this respect. This absolute dependence of the muscles upon the senses is very strikingly shown in the fact, that the deaf and dumb are dumb simply because they are deaf. The voice in them has no teacher.

390. The Involuntary Muscles not Edu-

cated.—The education of the muscles does not extend to those which are involuntary. Though respiration, for example, is a very complicated act of many muscles, these muscles require no education to do their part skillfully. We have no need to superintend them, for their constant action is secured by an arrangement for nervous influence which is independent of the mind.

So, while the mind sleeps, or when it is locked up in the stupor of disease, these muscles continue to perform their duty, as well as when we are awake. The same substantially can be said of the muscles which perform the act of swallowing. Although this is a very compound, and, mechanically considered, a very difficult act, it is performed as well in the first hour of the child's life as it is at any future period. The muscles that execute it need no training. And yet it is only after long and diligent training that the purely voluntary muscles, as for example those of the hand, execute movements which are no more complicated and difficult.

The reason for this difference is obvious. The movements which are performed by the involuntary muscles, such as breathing and swallowing, are immediately essential to the preservation of life, and it is therefore necessary that they should be well executed from the first. The voluntary muscles, on the other hand, instead of being devoted, like the involuntary, to the maintenance of life, act as the instruments of the mind, and therefore the mind acquires the power of using them skillfully only by dint of long-continued training.

391. Association of Action in the Muscles without Mental Action.—In the education of the muscles, it is to be observed, that although the mind, during the process of learning, at first takes distinct cognizance of every movement, it after a while, as the education becomes complete, takes little or no notice of many of the movements, except when some error occurs, or some obstacle arises. Thus, when one is learning to sing or play a tune, the mind, through the ear, at first takes a definite and distinct notice of every sound, and makes an appreciable exer-

tion in every movement. But after the tune is learned, this ceases to be the case, and the movements seem to be associated together, in some measure independently of mental action.

So in learning to walk, the child notices each of his movements very distinctly. When, however, he has fully learned, but little thought seems to be expended upon the motions, except when some obstacle appears which interrupts their regular succession. When one walks in a reverie, the mind is most of the time wholly abstracted from the associated movements which make up the compound act of walking.

In learning to read, the child makes a distinct mental effort in regard to each letter, resorting to every aid which will help to make the effort a successful one, even to putting the finger on each letter as he looks along the line. But as he becomes more and more skilled, the association of action comes more and more into play.

392. Offices of the Cerebrum and Cerebellum.—In the Chapter on the Nervous System, the different offices of the different central organs of this system were mentioned. The brain, as you have seen, is more especially connected with the mind, and is the great instrument through which mental manifestations are made. But it is only a certain part of the brain, the *cerebrum*, *a*, Fig. 110, that has this special connection with the mind. The *cerebellum*, *b*, Fig. 110, it is supposed, is especially devoted to the motions of the body, for in different animals it is developed in proportion to the range and variety of motion.

From extended observations on this point in comparative anatomy there seems to be good reason to conclude, that the cerebellum is the great central apparatus for combining the various compound motions of the body. It is uniformly found to be larger in those animals that have great complication in their muscular movements, than in those in which these movements are of a simple character.

Thus, in animals whose most complicated motion is walking, as the hooved quadrupeds, the cerebellum is much smaller than in those animals that climb and take hold of things

with their paws. In man it is much larger than in any other animal, for he walks erect, and thus brings into action a very large number of muscles in this delicate balancing movement (for such it is), and then, in the individual parts of the body, especially the hand, he executes a great range of very complicated movements. It is more developed in monkeys and apes than in any other of the inferior animals, because, with their capability of extensive variety of posture, and their power of seizing objects with their extremities, they obviously come nearer to man than any other animal in the varied combination of their muscular action.

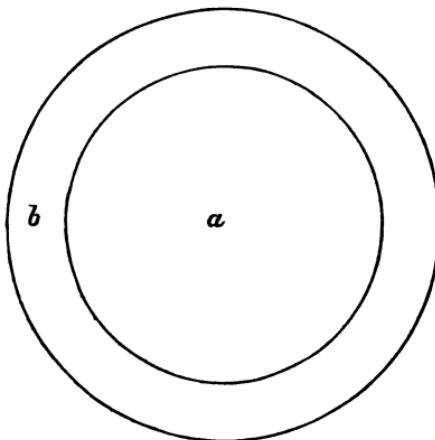
The conclusions thus arrived at by comparative observations in animals have been confirmed by experiments. It has been found by physiologists, that if the cerebellum be removed with as little disturbance as possible to other parts, although the sensibilities remain, and motions are performed, the power of combining muscular actions in definite compound movements, such as flying, walking, &c., is lost.

In relation to the cerebrum, we find that the amount of intelligence depends on the amount of its gray portion, the vesicular substance. In man, therefore, this part of the cerebrum is very much greater than it is in any other animal. It is the difference in the amount of the gray substance which constitutes the grand distinction between the brain of man and that of any of the higher orders of animals, for in all other respects his brain seems to differ little from theirs.

In looking at representations of the brain, as in Fig. 112, it would seem at first view that the gray substance, the working part of the cerebrum, is much less in amount than the white portion, which serves only for transmission. But this is not so. The eye is deceived, because the white substance is all together in one central mass, while the gray substance is spread out in an external layer. This is very plainly illustrated by Fig. 158. Here the area, *a*, contained in the inner circle, strikes the eye as being larger than the area, *b*, included between the two circles, and yet these areas are precisely equal.

Observe for a moment, in this connection, the concurrent evidence by which we determine what the function of the gray substance of the brain is. It comes from two sources. The first is that which is furnished to us by the structure of the cerebrum. As heretofore stated, the gray portion is made up of cells, while the white portion is composed of tubuli. These tubuli are such as we find in the nerves, and

FIG. 158.



in fact are continuous with them. We very properly infer, therefore, that as the nerves serve only for transmission, the white part of the brain does the same. It has, therefore, nothing to do with the thinking, and yet we know from other facts that this is done in some part of the cerebrum. So we necessarily infer that it must be done in the gray substance. And here, to confirm the truth of this inference, comes in one other source of evidence, viz., the comparison between different animals in regard to the correspondence between the amount of the gray substance and the amount of intelligence.

393. Facial Angle.—The size of the anterior portion of the brain, above referred to, may be estimated by the

measurement of the *facial angle*. This angle is formed by drawing two lines as represented in Figures 159 and 160. The line, *a*, *b*, is drawn from the most prominent part of the forehead to the front of the upper jaw. The line, *c*, *d*, is

FIG. 159.

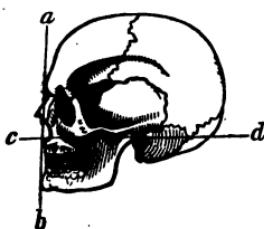
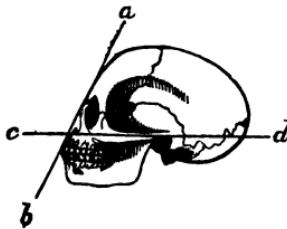


FIG. 160.



intended to represent the line of the base of the brain, and runs from the orifice of the ear along on the floor of the cavity of the nose. It is manifest that the less prominent is the forehead, that is, the less brain there is in the front part of the head, the more acute will the angle be that is formed by these lines. In Fig. 160, which represents the skull of a negro, this angle is more acute than in the skull of the European, Fig. 159. In animals this facial angle is much more acute than in man. In the monkey tribe it varies from 65° to 30° , while in man its average is about 75° . The ancient Greeks, wishing to give the aspect of great intellectual superiority to their statues of deities and heroes, made it in them as high as 90° .

It is proper to remark here, that while it is clear that, as a general rule, the amount of intelligence is to some extent proportioned to the amount of the cerebrum, both in man and in animals, the rule is not an invariable one. Size is far from being the only measure of power in this case. What differences there may be in intimate structure, to compare with the mental differences, we know not. Even where the rule stated above holds good, the difference in mere bulk is far from being proportionate to the mental difference. The mind of a Newton or a Shakspeare is gigantic compared with any common mind, but the brain in such cases is not very much larger than ordinary brains.

394. Mental Difference between Man and other Animals.—In relation to the evidence drawn from a comparison between different animals in regard to the functions of the nervous system, there is one significant fact which must not pass unnoticed. Though, as we rise in the scale of animal life in our observations, we find every new addition of functions coupled with some new additions of structure until we come to the higher animals, *we do not find this to be so when we pass from them to man.*

The brain, it is true, is larger in man than it is in them, and has much more of the gray substance; but there are no *essential* differences of structure in his brain, to correspond with the added mental qualities which so decidedly distinguish him from the brutes. These qualities constitute something more than a difference of *degree*. It is a difference of *kind*. And, therefore, it is a great and a significant fact, that there is no corresponding difference of kind in the organization of the brain.

The distinction between man and other animals is a definite one. It is as definite as it would be if it were based upon difference of organization. The barrier is fixed; and not a step over it has any animal advanced, with all the training which may have been expended upon him. No animal, however intimate his intercourse with man, has ever acquired man's habit of abstract reasoning, or manifested any real knowledge of the difference between right and wrong. Prof. Guyot does not speak too strongly when he says, "I will even go farther than is ordinarily done, and I will say, that there is an impassable chasm between the mineral and the plant, between the plant and the animal; *an impassable chasm between the mere animal and man.*"

395. Sources of Evidence in regard to the Nature of the Connection between Mind and Body.—The nature of the connection of the mind and the body is a great mystery. Still, there are many things which we can know in relation to it. The sources of our knowledge on this subject are three, viz., the investigations of *Physiology*, the testimony of *Consciousness*, and that of

Revelation. Each of these kinds of evidence throws light upon the others. If, therefore, we use all of them, giving to each its due limits and force, we shall come to some certain and valuable conclusions. But if we take any one of them alone, we shall be liable to be led into gross error.

In the investigation of this subject, there is in some physiologists a disposition to rely upon physiology alone, to the exclusion of the other sources of evidence. In doing this they are driven to this alternative: either they must be content with a very limited knowledge of the subject; or they must rely upon mere presumptive evidence for many of their conclusions. And commonly the latter is the course which they pursue. They are not content with the very limited conclusions to which they are shut up by the absolute proof furnished by physiology.

They boldly reason, therefore, upon what they deem to be probable. And they are invariably led into error.

396. Endowments of Matter.—In order to get definite ideas of the manner in which the erroneous conclusions are arrived at, let us view matter in its various states and connections. Unorganized dead matter, in some important respects, is entirely different from living organized matter. The distinction is a definite one. It is easily recognized, and none but dreamers in science have failed to see it.

Living matter is endowed with certain properties that dead matter has not. They are termed vital properties. They control to a certain extent the mechanical and chemical properties which both forms of matter have in common. Some suppose that what we call life is a single principle; but others suppose the endowment to be compound, made up of different principles or properties. But this question we need not discuss. All that concerns the view here presented is the mere fact of the endowment.

Let us go a step farther. Some living beings have more endowments than others. All have those of *organic life* in common. But there is an *animal life* also, which by means of the nervous system is superadded to the organic. And, as we trace the animal kingdom from the lowest animal up

to man, we find the endowments connected with this system multiplied as we advance, till in him they are more complicated and extensive than in any other animal.

This is especially true of intellectual endowments, those which are merely instinctive being more developed in many, perhaps we may say most, of the inferior animals. And in man we find special mental endowments, of which other animals present not the faintest trace.

397. Is Intelligence One of them?—Now the question arises, whether intelligence is like life, a mere endowment of matter, or whether it is in some measure independent of it. In other words, whether it is a principle or set of principles with which matter is endowed, or an immaterial something which acts through matter as its instrument. How much does bare physiology teach us on this question? It has often been claimed that it can teach us much, and the most bold conclusions have sometimes been ventured from this quarter. But mere speculation has in all such cases been deemed to be proof. Physiology does show us, as before stated, that the spiritual is in this world always connected with the material, and that mind never acts independently of the matter with which it is connected in the brain. But it gives us no light upon the *nature* of this connection. It is well for us to know how deficient are its teachings on this point.

For all that it can teach us, we know not but that the mind may be a mere result of action in matter. It neither tells us that it is so, or that it is not. It leaves us entirely in the dark on this point. Indeed so far as it affords presumptive evidence, it appears to teach, that mental phenomena are results of matter, acting in consequence of certain endowments or tendencies imparted to it, just as secretion is in living substances, or chemical action in those which are not living.

Accordingly those who have relied upon physiology alone on this subject, have adopted various forms of materialism. Some have supposed that thought is a mere product of matter, and that the brain secretes it as the liver secretes

bile. Others have taught that the mind is "a bundle of instincts," each residing in some particular part of the brain as its organ. This has been the doctrine of some prominent phrenologists.

Let us look at living matter in another point of view, and see to what physiology alone, if at all venturesome in drawing conclusions, will lead us. Let us look at the origin and growth of the thinking animal. Take, for example, an animal the formation of which we traced in the Chapter on Cell-Life. The beginning of the bird as it forms in the egg is a simple cell filled with a fluid. This produces other cells, and soon the organs and the limbs of the animal are formed. At length the animal bursts the shell, and comes out not only a living and sentient being, but a thinking being. It has a mind which feels desires and emotions, and prompts the muscles to action to effect its purposes.

Organization here precedes the development of mind so far as we can see, and therefore it would seem that mind is a result of organization. Especially does this appear to be so, when we find that the amount of mind in different animals is proportioned to the amount of a certain part of the organization, the brain. All this is as true of man as it is of other animals. And besides, we see in man that as the organization becomes perfected, the intelligence is proportionably increased.

In infancy, when the organization of the brain is imperfect, the intelligence is small in amount, and grows with the growth, and strengthens with the strength of the brain. And as the mind thus grows with the body, it appears to perish with the dissolution of the organization, and in the case of the inferior animals undoubtedly does so.

But the evidence from physiology does not all tend to materialism. There is some negative evidence which has a different bearing, in the fact that, while man differs in his spiritual nature so widely and so specifically from the inferior animals, his brain exhibits no corresponding specific difference in structure, but only a difference in amount. The difference in degrees of intelligence in the animals

below man is marked by a corresponding difference in the amounts of the gray substance.

And if it were true that man, as some think, differed from them only in having a higher degree of intelligence, we should expect to find in him a mere increase of this substance. But as his mind differs from theirs not merely in degree, but in kind also, we should have reason to expect, if mind were wholly dependent on organization, that the anatomist would find not only an increase in the quantity of the gray substance, but also a difference in its structure.

398. Physiologist needs other Evidence.—It is quite clear then, that the physiologist cannot well avoid materialism, if, in examining the connection between the mind and the body, he rejects all evidence beside that which physiology furnishes. He can be saved from this result only by being content with the narrow limits to which he is shut up, if he confine himself to *absolute* proof. As we have already seen, the positive knowledge that physiology gives us on this subject is exceedingly narrow. We soon come to the line that divides the known and the supposed. And if we attempt to go beyond that, our conclusions as to what is probable will quite certainly lead us to the result pointed out.

The need, therefore, of the evidence drawn from the other sources mentioned is most palpable. The physiologist must confess himself to be under the necessity of going out of his physiology, in order to learn all that can be learned upon this subject. At the best, there is much mystery in relation to it which we cannot penetrate, with all the light that we can bring to bear upon it. And the mystery is deep indeed, when we call to our aid only the dim light of physiology. It needs some other light to deliver us from the confusion of ideas, into which we are introduced by the analogy existing between the phenomena of life and instinct and intelligence, in relation to their connection with the organization of matter. Let us look then at the evidence which comes from the other two sources, viz., our consciousness, and revelation.

399. Consciousness.—Every individual is conscious that, as he feels and thinks and acts, he, that is, his mind or spirit, acts upon the structure of his body, and is acted upon by it. It is not a consciousness that he, as a *material body*, does all this. He feels that it is a power within that does it, and he instinctively separates in his ideas the power from the different parts of the body, and from the body as a whole. He is conscious, too, of a responsibility in relation to the thoughts and acts of the spirit within. He has a knowledge of right and wrong, and has self-reproach on doing wrong, and self-approbation on doing right.

It is this consciousness of a self-acting immaterial spirit in this material body, that constitutes the basis of all character, and of all the moral relations of man to his fellow-man, and to his Maker. Everybody acts upon the testimony of this consciousness as being valid and certain testimony. And, however the physiologist may reason about matter and mind, as if the latter were a mere product or endowment of the former, yet as a man, as a member of society, as a subject of government and law, he cannot avoid acting upon the ground that mind in a certain sense controls matter, and is responsible for its acts independently of the matter with which it is connected.

400. Evidence from Consciousness Confirmed by Revelation.—Now the evidence which this consciousness affords us should suffice to keep us from the materialism into which physiology taken alone would be apt to lead us. It shows us that, although the mind is developed with the material organization, and can act only with it, it is not its mere product, nor one of its endowments. It shows us, on the other hand, that it is in some measure independent of matter, and that its dependence upon it is only a dependence of connection, matter being the instrument of mind, through which it acts on external things, and is acted upon by them. The evidence from this source is of a positive character.

We are driven by it to the alternative of believing that

the mind is an immaterial, self-acting agent, in some measure independent of matter, or of harboring the impious and monstrous belief that the Creator has implanted in the bosom of man a lie, and that he is living a horrible farce, acting in view of moral relations and responsibilities that have no existence.

This positive testimony of our consciousness is confirmed by the testimony of revelation. This is not done by any formal array of proof. The existence of the spiritual part of man as a self-acting responsible agent is assumed as a fact that needs no proof. All the statements, and teachings, and appeals of the Bible recognize it as a fact known to the consciousness of every man. The Bible, therefore, may be considered as simply affirming that the testimony of our consciousness on this point is valid testimony.

But the Bible goes farther than this. It gives us one great fact of which neither physiology nor our consciousness could assure us, namely, the mind's immortality. Our consciousness could, it is true, give us presumptive evidence to show that the soul with its high powers and aspirations is to live after the death of the body. But it could furnish us no absolute proof of the fact. And its presumptive evidence would be effectually rebutted by the presumptive evidence from physiology, which, as you have seen, points in another direction.

We are so familiar with the mind's immortality as a known fact, and we so uniformly think of it in connection with the death of the body, that we are not aware how absolutely dependent we are upon revelation for all that we know in relation to it. If there were no revelation, and death were to us an unknown event, and we were now for the first time called upon to witness the death of a friend, how little should we know, and how confused would be our thoughts in relation to the great mystery before us! "What is it?" we should ask. "Is it sleep? No. We never saw any one sleep thus. What is it? Who can tell us?" And we should wonderingly watch to see some signs of awaking, not giving up all hope till decay begins its ravages on

the loved form before us. Then, as we should from the dictate of nature, consign to the earth the friend who was so recently among us a breathing, moving, speaking man, now a mere mass of decaying matter, we should feel that we bury there not the body only, but all that belonged to that body during life—the whole man.

Thought and feeling, as well as life and motion, would appear to us, untaught of God, to be extinguished in the grave. Even if some one should utter all tremblingly the hope that there might be a subtle, spiritual part of our friend that would some time, in some form, return again to our society, that hope would at once be crushed by the reflection that whatever it was in our friend that thought and felt, it came into existence with the body, was infantile when the body was, grew with the growth of the body, and strengthened with its strength, and therefore now, so far as we can see, has perished with it. Nature utters no voice to tell us otherwise. She emits no light to illuminate the grave. Darkness and silence rest there, till the light of revelation shines upon it, and God proclaims man's immortality.

Your attention has been called to the three sources of evidence in regard to the connection of the mind and the body, and the character of the evidence furnished by each has been indicated. It has been shown particularly that if the attention be confined to that which is furnished by physiology, the mind is apt to be led into materialism. But the attention should not thus be confined. All the three kinds of evidence should be employed and should be brought to bear upon each other.

If this be done, the discrepancies in the evidence from physiology are cleared up by the evidence afforded by consciousness and revelation, and we see the true value and bearing of the fact, that the specific mental difference between man and animals is not attended with a corresponding structural difference. Though this fact operates merely as conflicting evidence, when taken simply in connection with the rest of the facts developed by physiology; when we come, on the other hand, to take the whole range of evidence

from the three sources spoken of, it is exceedingly satisfactory as concurring with the testimony of consciousness and revelation.

At the same time, those physiological phenomena, which taken by themselves seem to show so strongly that the mind is wholly dependent upon organization, are so interpreted by the evidence from the other sources, that the dependence is seen to be for the most part a dependence of connection only, the brain being the instrument of the mind.

The evidence from consciousness and revelation is of the most positive character, and can not be set aside by evidence from any other source. Other evidence may serve to interpret it, but can not nullify it. The attempt is sometimes made to set it aside by urging the presumptive evidence of physiology, as if it were absolute proof. But most physiologists engage in no such futile and unchristian efforts, but give due weight to the testimony of consciousness and revelation in all their investigations of the mysterious connection of the mind and the body.

The influence of Carpenter, an English physiologist, whose works are more extensively used by students than those of any other physiologist, is especially to be commended in this respect. And although skepticism occasionally utters its plausible falsities, deceiving the superficial and the speculative, we have no fears from present indications that the votaries of physiological science will, as a body, be arrayed in opposition to Christianity.



CHAPTER XVIII.

DIFFERENCES BETWEEN MAN AND THE INFERIOR ANIMALS.

THE differences between man and the inferior animals have been alluded to in different parts of this book, and especially

in the preceding chapter. But it has been done only incidentally, and the subject demands at our hands a more thorough and systematic investigation.

401. Views of Lord Monboddo.—Lord Monboddo maintained that man is only an improvement on the monkey, occurring as a result from the general tendency to advancement claimed to exist in nature. He seemed to think that man bore a relation to the monkey somewhat like that which the frog bears to the tadpole, and that as the tadpole becomes the frog, so the race of man was produced by a change, at some remote period of the creation, of the monkey into the man.

This ridiculous notion of the erudite but fanciful Scotch philosopher is really but another phase of the more recent theory of gradation, or development, as it is sometimes called, which in different forms is now advocated by so many European philosophers. And, although few, comparatively, adopt this theory definitely and fully, there is quite a disposition among many to obliterate the distinctions by which the Creator has in so marked a manner separated man from the inferior animals. It is well, therefore, that we should have a clear idea of these distinctions.

It is often very loosely said that while man is governed by reason, instinct rules in the animal.* If it be meant by this that, as a general rule, reason predominates in man, while instinct does so in animals, the statement is a correct one. But if it be meant that animals are wholly governed by instinct, and that man is distinguished from them as a reasoning animal, it is not correct. For some animals do reason, that is, if making inferences be considered as reasoning.

* Some explanation may be well here in relation to the different uses made of the word animal in different connections. Here it is used in contradistinction to man. So it is used in the expression, man and animals. But as man is in certain senses an animal, whenever we wish to recognize this fact we speak of other animals as the *inferior* animals. And thus, in regard to animals, we speak of their higher and lower orders, the higher of course being those that approximate nearest to man.

In tracing out the difference between man and animals no attempt will be made to show what the nature of instinct is. This is a great mystery, and all attempts to solve it have utterly failed. Let us examine some of the differences between instinct and reason. In doing this it is not always easy to say just where the one begins and the other ends, so intimately are their phenomena often mingled together.

The actions of instinct are more unaccountable than those of reason. In the operations of reason we see something of the processes by which results are reached. For example, as a man travels over an unexplored country, we can understand by what means he obtains a knowledge of the country, in order to guide him on his journey. The processes of his reasoning in regard to this we can comprehend.

But when an insect travels with unerring certainty to its place of destination without any guide-marks that we can see, or when a swarm of bees or a flock of birds wing their flight to distant places, or when bees construct their honey-comb with the exactness of mathematics in obedience to the best principles for such a structure, we can not understand the processes which lead to the result. It seems to be produced by an impulse from a cause extraneous to the animal, guiding it as if it were a mere machine. The little intelligence of the animal seems to have only an incidental connection with this impulse. It, therefore, merely controls somewhat the circumstances under which the instinct acts.

402. Instinct Governed by Invariable Rules.

—So little has the intelligence to do with the instinct, and so nearly mechanical therefore are the actions of the latter, that they are governed by an invariable rule. It is nearly as invariable as are the movements of a machine. For this reason there are no improvements or alterations in the acts of instinct.

The bird and the bee, for instance, have no change of fashion in their architecture from age to age. The honey that fed John the Baptist, or that which was found by Samson in the carcass of the lion, was deposited in the same hexag-

onal cells which are constructed by the bees of the present day.

403. Contrivances in the Nests of Birds.—Each bird builds its nest precisely in the same way that its ancestral birds have ever done. Most birds' nests are constructed after the same general pattern. But sometimes we observe striking peculiarities to subserve some special purpose.

Fig. 161 represents the nest of the Baya, a little bird of Hindoostan. It is in the shape of a bottle, and is made of

FIG. 161.



NEST OF THE BAYA.

long grass. It is suspended from a slender branch of a tree, so that monkeys, serpents, &c., cannot reach it. The entrance to the nest is made on the under side, so that these animals cannot enter, while the bird itself can readily fly in. It is divided into apartments, in one of which the female sits upon the eggs, while in the other the male bird "solaces his companion with his song whilst she is occupied in maternal cares." In Fig. 162 is seen the nest of another little eastern bird, which with filaments of cotton taken from the cotton plant, sews leaves together with its beak and feet, so as to conceal the inclosed nest from its enemies.

404. Contrivances in the Honey-comb.—

While there is no change in the acts of instinct they are marked by perfection. There is nothing in which this perfection of instinct is better shown than in the construction of the honeycomb.

FIG. 162.



NEST
of the Tailor Bird.

The cells are made hexagonal, because in this way all the space is occupied—there is no waste of room. If the cells were made circular, there would not only be a waste of room, but a large quantity of material would be needed to fill up the spaces between the cells. The difference can be seen in the two Figures 163 and 164. Each comb, it is to be observed farther, has two sets of cells, the ends of one set being arranged against the ends of the other in a peculiar manner. These ends are not flat, but each one has three plane surfaces, forming with each other a particular angle soon to be noticed, and uniting together at the center in a point. In the arrangement of these cells, therefore, a cell of one set does not lie end to end with a cell of another set.

Its three surfaces form a part of the bottom or end of three cells of the other set. This is made

FIG. 163.

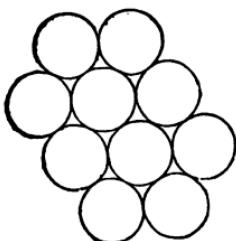


FIG. 164.



clear by Fig. 165, in which a cell of one set is represented as it abuts against a cell of the other set by one of

its surfaces, its other two surfaces forming a third part of the ends of two other cells.

Now it has been found that the angle formed at the edge of these surfaces between the two sets of cells is such as to secure the greatest strength with the least amount of material. It was at one time thought that this was proved to be not exactly true. The variation from the correct angle, made out by the calculations of the mathematicians, was indeed a slight one, but still it was variation enough to show, if the calculations were correct, that the workings of instinct were not perfect in this case. But the investigations of Lord Brougham have satisfactorily shown that the mathematicians were wrong in their calculations, and that the bees are right.

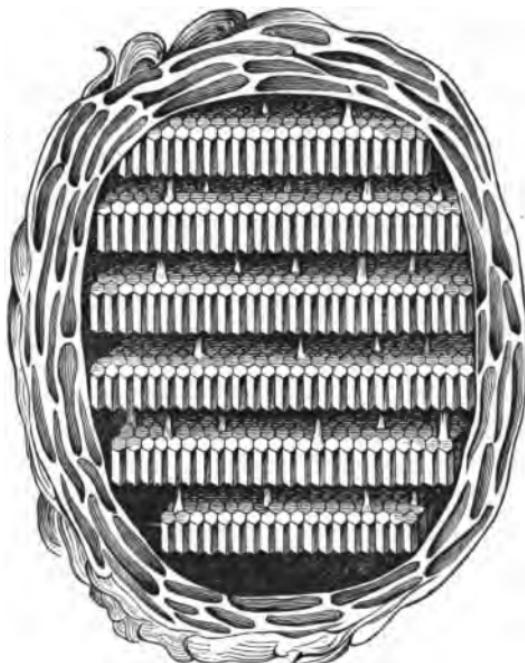
FIG. 165.



405. Wonderful Operations of Instinct in Communities among Animals.—The perfection of the operations of instinct is shown in the most wonderful manner in the regulation of *communities* of animals. Here we see coöperation to produce results effected through an irrational, and therefore in some measure a blind instinct. This social instinct is most extensively exemplified among the insect tribes, as for instance the bee and the wasp. The structures resulting from the coöperation of multitudes of little laborers guided by this instinct, are very interesting. Take but a single familiar example, the construction of the nests of wasps. These insects make their building material from the fibres of old wood. These they convert by mastication into a pulp, which made into a thin layer, becomes firm like paper. It is indeed a process very much like the common process of paper-making invented by man, and the first rude inventor may have got his idea from the insect. With this substance the wasps build several ranges of cells, which are hexagonal, like the cells in the comb of the bee. These ranges of cells are placed parallel to each other, at regular distances, with little supporting columns between them, as seen in Fig. 166.

The number and variety of instincts of the ordinary hive bees are very wonderful, but it would occupy too much space to describe them.

FIG. 166.



NEST OF WASPS.

406. Exemplified in the Beaver Community.—The wonderful coöperation of animals in obedience to social instinct, in the building of habitations and other structures, is seen in several of the mammalia. But it is most wonderful in the beaver, the following description of whose habits in this respect is taken from Carpenter:

“During the summer it lives solitarily in burrows, which it excavates for itself on the borders of lakes and streams; but as the cold season approaches it quits its retreat and unites itself with its fellows, to construct, in common with them,

a winter residence. It is only in the most solitary places that their architectural instinct fully develops itself. Having associated in troops of from two to three hundred each, they choose a lake or river, which is deep enough to prevent its being frozen to the bottom ; and they generally prefer running streams, for the sake of the convenience which these afford in the transportation of the materials of their erection.

"In order that the water may be kept up to a uniform height, they begin by constructing a sloping dam ; which they form of branches interlaced one with another, the intervals between them being filled up with stones and mud, with which materials they give a coat of rough-cast to the exterior also. When the dam passes across a running stream, they make it convex towards the current; by which it is caused to possess much greater strength than if it were straight. This dam is usually eleven or twelve feet across at its base, and is enlarged every year; and it frequently becomes covered with vegetation so as to form a kind of hedge.

"When the dam is completed, the community separates into a certain number of families; and the beavers then employ themselves in constructing huts, or in repairing those of a preceding year. These cabins are built on the margin of the water; they have usually an oval form, and an internal diameter of six or seven feet. Their walls are constructed, like the dam, of branches of trees; and they are covered, on two of their sides, with a coating of mud. Each has two chambers, one above the other, separated by a floor; the upper one serves as the habitation of the beavers, and the lower one as the magazine for the store of bark, which they lay up for their provision. These chambers have no other opening than one by which they pass out into the water.

"It has been said that the flat oval tail of the beavers serves them as a trowel, and is used by them in laying on the mud of which their houses are partly composed; but it does not appear that they use any other implements than their incisor

teeth and fore-feet. With their strong incisors they cut down the branches and even the trunks of trees which may be suitable ; and by the aid of their mouths and fore-feet, they drag these from one place to another.

“ When they establish themselves on the bank of a running stream, they cut down trees *above* the point where they intend to construct their dwellings, set them afloat, and, profiting by the current, direct them to the required spot. It is also with their feet that they dig up the earth they require for mortar, from the banks or from the bottom of the water. These operations are executed with extraordinary rapidity, although they are carried on only during the night. When the neighborhood of man prevents the beavers from multiplying to the degree necessary to form such associations, and from possessing the tranquillity which they require for the construction of the works just described, they no longer build huts, but live in excavations in the banks of the water.”

407. *Blindness of Instinct Exemplified.*—Instinct moves straight on to its result, and it does so blindly. It exercises no intelligence in regard to the purpose for which the result is intended, or the circumstances which tend to defeat this purpose. It evidently in some cases never knows any thing of the purpose aimed at by its acts, as, for example, when an animal makes provisions for a progeny which it is never to see.

“ It is scarcely possible,” says Carpenter, “ to point to any actions better fitted to give an idea of the nature of instinct, than those which are performed by various insects when they deposit their eggs. These animals will never behold their progeny ; and can not acquire any notion from experience, therefore, of that which their eggs will produce ; nevertheless they have the remarkable habit of placing, in the neighborhood of each of these bodies, a supply of aliment fitted for the nourishment of the larva that is to proceed from it ; and this they do, even when they are themselves living on food of an entirely different nature, such as would not be adapted for the larva.

"They can not be guided in such actions by any thing like *reason*; for the data on which alone they could reason correctly, are wanting to them; so that they would be led to conclusions altogether erroneous if they were not prompted by an unerring *instinct*, to adopt the means best adapted for the attainment of the required end."

408. Results of Instinct mingled with those of Reason.—The results of reason are often mingled with those of instinct in such a way that it is difficult to distinguish them from each other. But instinct is of itself wholly *irrational*. If it were not so, it would avoid acting whenever action would evidently be useless. But instinct has not the eyes of reason to see when this is the case. It leads the animal blindly on; so that, although under all *ordinary* circumstances the object is accomplished definitely and in the best manner, yet there is no capability of making provision for *extraordinary* circumstances. Therefore, actions are occasionally performed which do not at all answer the purpose which the instinct is designed to effect.

Instinct, though perfect in its action under the uniform circumstances under which it is destined to act, is a kind of blunderer when irregular circumstances arise. Instinct is a strict routinist, while reason readily accommodates itself to endlessly varying circumstances. In illustration of the above characteristic of instinct, take a few examples:

The hen will sit on pieces of chalk shaped like eggs, as readily as she will sit on the eggs themselves. The flesh-fly often lays its eggs in the carrion-flower, the odor of which is so much like that of tainted meat as to deceive the insect.

409. Blindness of Instinct Illustrated in the Beaver.—An amusing illustration of the blind disregard of circumstances in following out the promptings of instinct is given by a gentleman, Mr. Broderip, in an account of a beaver which he caught when very young. As soon as it was let out of its cage, and materials were placed in its way, it began to build after the fashion followed by these animals when they construct their dam in a stream of water and build their habitations in its banks. "Even

when it was only half grown," says Mr. B., "it would drag along a large sweeping-brush, or a warming-pan, grasping the handle with its teeth, so that the load came over its shoulder; and would endeavor to lay this with other materials, in the mode employed by the beaver when in a state of nature. The long and large materials were taken first; and two of the largest were generally laid crosswise, with one of the ends of each touching the wall, and the other ends projecting out into the room. The area formed by the cross-brushes and the wall, he would fill up with hand-brushes, rush-baskets, books, boots, sticks, cloths, dried turf, or any thing portable.

"As the work grew high, he supported himself on his tail, which propped him up admirably; and he would often, after laying on one of his building materials, sit up over against it, appearing to consider his work, or as the country people say, 'judge it.' This pause was sometimes followed by changing the position of the material judged; and sometimes it was left in its place. After he had piled up his materials in one part of the room (for he generally chose the same place), he proceeded to wall up the space between the feet of a chest of drawers which stood at a little distance from it, high enough on its legs to make the bottom a roof for him; using for this purpose dried turf and sticks, which he laid very evenly, and filling up the interstices with bits of coal, hay, cloth, or any thing he could pick up.

"This last place he seemed to appropriate for his dwelling; the former work seemed to be intended for a dam. When he had walled up the space between the feet of the chest of drawers, he proceeded to carry in sticks, cloths, hay, cotton, &c., and to make a nest; and when he had done, he would sit up under the drawers, and comb himself with the nails of his hind feet." If the instinct of this animal had been at all rational, it would not have impelled him to construct a dam and a dwelling in a common room, where they would be of no use to him. Reason would have dictated the building of a nest and nothing more.

410. Care for Progeny.—The care which animals

exercise in relation to their progeny seems to be governed to a great extent, perhaps wholly, by a blind instinct. All care is given up when care is no longer needed, and with it what appears to be affection is given up also. In animals there is no such lasting affection of the parent for the progeny as there is in man; for in them it is merely instinctive, and not rational and moral in its character, and it, therefore, lasts only so long as it is needed to carry out the purposes for which this particular instinct is designed. Indeed, in some cases there can be no affection in all the care which is instinctively exercised by the parent, for it is put forth for progeny which the animal is destined never to see.

And in those cases among animals in which the family state exists, it is a mere temporary affair, and as soon as the offspring is able to take care of itself it is no more to the parent than any other animal of the same tribe is.

411. Some Animals have Intelligence as well as Instinct.—When this intelligence is shown in the mere power of imitation it is of a low order. The parrot that learns to imitate man in speech is not nearly so intelligent as some animals that have no such power. Some animals have really a *reasoning* intelligence—that is, they make rational inferences. Their reasoning is sometimes, as before remarked, so mingled with the operations of instinct, that it is difficult to distinguish them accurately.

In the case of the beaver, who labored so faithfully in obedience to a blind instinct, there was some exercise of reason, as, for example, when he “judged” his work. But it is difficult to point out definitely the line between instinct and reason in such a case. There are some animals, however, in whom the workings of a reasoning intelligence are to be seen with perfect distinctness. But their reasoning differs from that of man.

The inferences which the reasoning animal makes are individual; while man goes beyond this, and makes general inferences, and therefore discovers general truths. Newton's dog, Diamond, saw apples fall to the ground, as well as his master. And he was capable of making some

inferences in regard to them ; but they were individual inferences.

For example, if an apple-tree were shaken, and the dog were hit by a falling apple, whenever he saw other apples falling he would infer that he might be hit again, and would infer also that it was best for him to get out of harm's way. This would be the extent of his reasonings. But his master inquired into the cause of the fall of the apple, and by considering this and other similar phenomena, he deduced general principles, which govern the movements both of the atoms and the worlds of the universe.

The inferences which are formed by animals are mere results of the association of ideas, and the process, therefore, really hardly merits the appellation of reasoning. Thus, in the case of Newton's dog, supposed above, the idea of the falling apples was associated in his mind with the hurt experienced when he was hit, and prompted the getting out of harm's way.

When such associations are extended and complicated, it appears at first thought as if the animal acted in view of general truths arrived at by the same process of reasoning that man employs. But it is a mere extension of mental associations. Thus, Newton's dog probably associated the idea of being hit and hurt with other falling bodies beside apples. And so, too, various circumstances might come to be associated with the falling of bodies, and thus complicate the mental process which occurred when he saw any object falling near him.

412. Reasoning in Animals mere Mental Association.—To show somewhat the extent to which this mental association operates in the brute mind, some examples will be given. A wren built its nest in a slate quarry, where it was liable to great disturbance from the blastings. It soon, however, learned to quit its nest and fly off to a little distance, whenever the bell rang to warn the workmen previous to a blast. As this was noticed, the bell was sometimes rung when there was to be no blast, for the sake of the amusement in seeing the poor bird fly away

when there was no need of alarm. At length, however, it ceased to be deceived in this way, and when it heard the bell ring it looked out to see if the workmen started, and if they did, then it would leave its nest.

In this case the bird merely learned to connect in its mental associations two circumstances with the blasting, instead of the one from which it at first took the warning. The operation of this mental association is shown in a little different manner in the following case :

Some horses in a field were supplied with water in a trough which was occasionally filled from a pump. As the supply was not always sufficient, one of the horses, more sagacious than the rest, whenever he, on going to drink, found the trough empty, pumped the water into it by taking hold of the pump-handle with his teeth, and moving his head up and down. The other horses seeing this, would, whenever they came to the trough and found it empty, tease the one that knew how to pump, by biting and kicking him till he would fill the trough for them.

In this case the horse that did the pumping *associated* in his mind the motion of the pump-handle, as he had seen it done by his master, with the supply of water. And while they *associated* this supply with his pumping, he knew what their teasing him meant, because he *associated* it with their motions about the trough, indicating so plainly that what they wanted was water.

A dog belonging to a Frenchman was observed to go every Saturday, precisely at two o'clock, from his residence at Locoyarde to Hennebon, a distance of about three-quarters of a league. It was found that he went to a butcher's, and for the purpose of getting a feast of tripe which he could always have at that hour on Saturday, their day of killing. It is also related of this dog, that at family prayers he was always very quiet, till the last *paternoster* was commenced, and then he would uniformly get up and take his station near the door, in order to make his exit immediately on its being opened.

The narrator of these facts thinks that the first fact shows

that the dog could measure time and count the days of the week. But this can not be so. The dog undoubtedly associated in his mind the time at which he could get the tripe with something that occurred on Saturday at that hour at his master's house, just as he associated the concluding of family prayers with something that occurred as the last *paternoster* was read, perhaps with some peculiarity in the manner of his master when he came to that part of the service.

413. Relation between Cause and Effect learned from Association.—Animals learn the relation between cause and effect by this mental association, and act upon the experience thus gained. This is manifest in the examples cited. And it may be observed in many acts that we witness occasionally in the higher animals. Thus, for example, as a horse was cropping some grass, he took hold of some that was so stout, and yet so loosely set in the ground, that he pulled it up by the roots, and, as the dirt which was on it troubled him, he very deliberately knocked it across the bar of a fence till he got all the dirt out, and then went on to eat it.

Here was a knowledge of cause and effect which was derived from previous experience through mental association. You see the same thing when you see a cat jump up and open the latch of a door, or a horse unbolt the stable door to get out to his pasture. But in all such cases the knowledge of cause and effect differs from the same knowledge in man in one important particular. In the animal it is always an individual knowledge, that is, a knowledge of individual facts; while in man it is often a knowledge which has relation to general truths or principles.

From the facts stated in the last few paragraphs, it is clear that Carpenter is not correct in saying that "the mind of man differs from that of the lower animals rather as to the *degree* in which the reasoning faculties are developed in him, than by any thing peculiar in their *kind*." While there is much in common between them in their modes of mental action, especially if man be compared with

other animals in the period of his infancy and childhood, there is, as you have seen, one attribute of the human mind which is wholly peculiar to it, and never exists in any degree in any other animal. And this attribute, the power of abstract reasoning, or in other words, the power of deducing general truths or laws from collections of individual facts, constitutes the great superiority of the human mind, in distinction from the mind of the brute.

414. Language.—It is this attribute which is the source of language in man. This can be readily seen by observing what is the nature of language. It is a collection of corresponding vocal and written signs of an arbitrary character, arranged according to certain general rules or principles. Other animals do have a kind of language of a very limited character. It is the language of natural signs. It is composed of cries and motions, which vary in different tribes of animals, so that each tribe may be said to have its own natural language. But animals never invent and agree upon any arbitrary signs, as is done continually by mankind in the construction and extension of language. This they can not do, because abstract reasoning is required for such an invention. General principles are observed in the construction and arrangement of arbitrary signs, and, as has been shown, brutes know nothing of principles.

415. The Source of Man's Belief in a Creator.—If he had not the power of deducing general truths from individual facts, he could neither discover the truth that there is a first great Cause, nor appreciate or even receive it, if it were communicated to him. Not the faintest shade of such an idea can be communicated to any of the inferior animals, however high their mental manifestations may be, and simply because the structure of their mind is such that they know nothing of general principles.

Carpenter speaks of the disposition to believe in the existence of an unseen but powerful Being, which is found to be universal even among the most degraded races of mankind, as a natural tendency, which he seems to think is implanted in the human breast by the Creator. But it ap-

pears clear, that it is a mere natural result of the exercise of the power that has just been mentioned.

416. Conscience.—Man differs from other animals also in having a conscience, or a knowledge between right and wrong, and a sense of obligation in relation to it. This moral sense is supposed by some to be a mere result of the exercise of the power of abstract reasoning. But others suppose that the sense is implanted as a distinct quality or power, and that the office of the reasoning power in relation to it is to bring the evidence before it for its decision.

This point will not be discussed, but that there is no doubt as to the existence of such a sense in man. Some attempt to throw doubt over it by pointing to its perversions, maintaining that it is a mere creature of circumstances, varying almost endlessly in different parts of the world. But it would be just as rational to attempt to show that there is no such thing as a sense of the beautiful in man, by appealing to the evidences of perversions of taste, which ignorance, bad education, and foolish and novelty-loving fashion have induced.

417. None in Animals.—In those cases in animals in which this moral sense has been supposed to exist, it is nothing but slavish fear. It has been said by some one that man is the god of the dog; but it is trifling with what is sacred to compare the attachment of an animal to its master and its fear of his displeasure, with the intelligent regard of man for his Creator as a holy and benevolent being. We ordinarily recognize the distinction between man and animals, as to the existence of a conscience, in the language we use.

We never attach the idea of moral character to the acts of an animal except by the force of association, and then only slightly and loosely. We are not apt to speak of *punishing* a dog, for this word implies a moral fault as the occasion of the infliction. We *whip* him, sometimes, simply to associate in his mind the smart with the act done, so as to prevent him from doing it again, and sometimes to vent our ill feeling for the harm done us on the poor dog that has so innocently done it.

It is related of Sir Isaac Newton that he had a favorite little dog called Diamond, who being left in his study, overset a candle among his papers, and thus burnt up the almost finished labors of many years, and yet the philosopher only said, "O Diamond! Diamond! thou little knowest the mischief thou hast done." Newton was a wise and good man, and while he saw that whipping the dog would do no good in preventing any similar accident in the future, he had no ill feeling to vent on poor Diamond, who certainly had a better and more rational master than most dogs have.

418. Summary of Mental Distinction.—The mental distinction between man and animals may be thus summed up. The animal is governed by instinct, and in the higher orders by a kind of reasoning which is based upon mental association. Man has, in addition to instinct and this lower order of reasoning, the power of abstract reasoning. In the lower orders of animals probably instinct rules alone. In them there is none even of the limited reasoning which we see in the higher animals. They have a nervous system with certain central organs, but have really no one great central organ that we can call the brain. As we trace the animal kingdom upward, we soon find that a brain appears, that is, such an organ as may be considered the chief center of the nervous system. When we come to man the brain is much larger than in any other animal, and his intelligence is not only greater, but it is of a different character. Not only is the amount of his reasoning by association greater than in other animals, but there is also superadded, as his grand distinguishing mark, the power of abstract reasoning.

CHAPTER XIX.

VARIETIES OF THE HUMAN RACE.

419. Mankind all the Same Species, but Presenting very marked Varieties.—Although, as we look at men of different nations, we find that there is a general agreement in form and organization, there are many points in which they strikingly differ from each other. “With those forms, proportions and colors,” says Mr. Lawrence, “which we consider so beautiful in the fine figures of Greece, contrast the woolly hair, flat nose, thick lips, retreating forehead, advancing jaws, and black skin of the negro; or the broad square face, narrow oblique eyes, beardless chin, coarse straight hair, and olive color of the Calmuck.

Compare the ruddy and sanguine European with the jet-black African, the red man of America, the yellow Mongolian, or the brown South Sea Islander; the gigantic Patagonian to the dwarfish Laplander; the highly civilized nations of Europe, so conspicuous in arts, science, literature, in all that can strengthen and adorn society, or exalt and dignify human nature, to a troop of naked, shivering, and starved New Hollanders, a horde of filthy Hottentots, or the whole of the more or less barbarous tribes that cover nearly the entire continent of Africa;—and although we must refer them all to the same species, they differ so remarkably from each other as to admit of being classed into a certain number of great varieties; but with regard to the precise number, naturalists have differed materially.”

Cuvier admitted but three varieties, the *Caucasian*, *Negro*, and *Mongolian*. The more commonly received classification, however, is that of Blumenbach, who makes five varieties, viz., the *Caucasian*, *Ethiopian*, *Mongolian*, *American*, and *Malay*.

420. Caucasian.—The chief characteristic of the *Caucasian* variety is the fine form of the head, it being nearly oval, as you view it from the front. It is also characterized by a great range of variations of the color both of the skin and the hair. There has been more of civilization and improvement of every kind in this race than in any of the others. It is mentally superior to the other races. It is called Caucasian from Mount Caucasus, from the vicinity of which, it is supposed, it originated. Even at the present day it is said that the characteristics of this race are most perfectly developed in the Georgians and Circassians, who live in the neighborhood of this range of mountains, and who are considered the handsomest people in the world.

421. The Ethiopian Variety.—The organization has not the perfection and elegance which the Caucasian presents, and it shows an approximation to the higher orders of the inferior animals. The skull is small. The forehead is retreating, while the face below is projecting, the cheek bones being prominent, and the nose broad. The apparatus of the senses is thus fully developed, while the brain is less than in the Caucasian. The hair is black, oily, and frizzled. It is commonly said to be woolly, but it is really not so. Dr. Carpenter says that “microscopic examination clearly demonstrates that the hair of the negro has exactly the same structure with that of the European, and that it does not bear any resemblance to wool save in its crispiness and its tendency to curl.” The skin is generally black; but not so in all the race; for the Caffirs and the Hottentots are yellow.

422. The Mongolian Variety.—The Chinese race forms the largest family and is characterized by prominent broad cheek bones, flat square face, small oblique eyes, straight black hair, scanty beard, and olive skin.

423. The American Variety.—Characterized by high cheek bones, a narrow low forehead, features large and bold, except the eyes, which are deeply sunken in large sockets, hair generally black, stiff and straight, and complexion varying from a crimson brown to a deep copper.

424. The Malay Variety.—This variety occupies the Islands south of Asia, in the Indian and Pacific oceans, and has not so well marked characteristics as the other varieties. The complexion is brown, varying from a light tawny to almost black, the hair is black and thick, the forehead is low and round, the nose is full and broad, the nostrils wide, and the mouth large.

425. Differences in Individuals, Families and Nations—produced by Similar Causes.—The *national* differences are evidently produced by causes of very much the same character with those which produce differences in individuals and families. And the question arises whether such differences as those which Blumenbach describes as marking the races, are not produced in a similar manner. This question has been much discussed, and there is great difference of opinion in regard to it. The great majority of naturalists believe in the unity of the origin of the human race, and hold that its varieties are the results of the various circumstances by which man has been surrounded.

But some suppose that the different varieties come from separate pairs created by God in different localities, and hold that the history in Genesis is a history of the origin of only one of the varieties of the race. Those who advocate this doctrine are few in number; but it has acquired greater currency of late, because one of the most eminent naturalists, Professor Agassiz, espoused it.

426. Views of Prof. Agassiz.—All animals, he asserts, like plants, have particular localities, for which they are fitted, and to which they belong. The zoological provinces, as he terms them, are of unequal extent, some animals having a wider range than others. From this general law of distribution, which he illustrates with many facts, he infers that the various animals on the face of the earth were not created in one part of the earth and distributed from this to other parts, but were created in the provinces to which they belong.

This view of the subject forces itself upon the mind of

the naturalist, as he observes the arrangement of the various tribes of animals on the earth's surface. And besides, there are apparently insurmountable difficulties in the way of a diffusion of animals over the globe by means of migration. For example, we can not conceive how the polar animals could have migrated over the warmer tracts of land, which they would have to cross according to this supposition, for, with the greatest precautions, it is impossible now to keep them alive in such circumstances.

And farther, some animals of the same species, sometimes presenting varieties and sometimes not, are found in different localities, which are so cut off from all communication with each other that it is impossible that these animals could migrate from some one locality to all the rest. "To assume," he remarks, "that the geographical distribution of such animals, inhabiting zoological districts entirely disconnected from one another, is to be ascribed to physical causes, that these animals have been transported, and, especially, that the fishes which live in fresh water basins have been transported, from place to place—to suppose that perch, pickerel, trout, and so many other species found in almost every brook and every river in the temperate zone, have been transported from one basin into another by freshets or by water-birds—is to assume very inadequate and accidental causes for general phenomena." Not only then were different species of animals created originally in different localities, but it is also true, to a considerable extent, that animals of the same species occupying different localities were created in those localities.

All this he claims to be consistent with scripture, and with very good reason. The account of the preservation of animals in the ark, interpreted according to the common license of language, indicates really only such a preservation as would be necessary for the stocking of that part of the world where Noah and his family were, after the waters should subside. The number and the variety of the animals preserved for this purpose would of course be very great, and would, according to the common usage

of language in narration, be spoken of in the terms used in the Bible. This interpretation holds equally, whether the deluge be considered as having been partial or universal.

The case being thus quite clearly made out in relation to animals generally, he proceeds to trace an analogy between them and the races of man in this respect. He supposes that there are certain zoological provinces for the different human races, as there are for the different species and varieties of animals; and that these races were separately created in these provinces with organizations suited to their peculiar localities. While he allows that climate and other influences affect the varieties of the human race, he claims that they alone are not competent to produce them, and he infers, therefore, that there must have been, as in the case of animals, different original creations in the different zoological districts. He accordingly claims that the history given in Genesis is a history of the origin of only one branch of the human family. He does not suppose that the different branches constitute different species, but are made varieties of one species.*

He characterizes mankind as being every where essentially the same in mental character, and alike the accountable subjects of God's kingdom, notwithstanding their multiple origin. It is in this respect that he considers them as being of one brotherhood, and he looks upon the expression in

* The difference between *species* and *varieties* is this: The distinction of *species* rests upon *specific* characteristics, that can not be changed by those influences which tend to produce the differences that make *varieties*. The characteristics of a species are *original*, while those of a variety are *acquired*. "The term species," says Prichard, "includes only the following conditions, namely, separate origin and distinctness of race, evinced by the constant transmission of some characteristic peculiarity of organization. A race of animals or of plants marked by any peculiarity which it has ever constantly displayed, if termed a species; and two races are considered specifically different, if they are distinguished from each other by some characteristic which the one cannot be supposed to have acquired, or the other to have lost, through any known operation of physical causes."

the Bible, "made of one blood," as being entirely figurative, and as referring to "the higher unity of mankind, and not to their supposed connection by natural descent."

We will not go into a thorough discussion of this question, as it is not possible in the narrow limits of a chapter. Only a general view of the chief facts and arguments that bear upon the point at issue will be presented. Let us look at this subject first in the light of physiology and natural history.

The great majority of physiologists and naturalists, as has been remarked, have thus far been of the opinion that the human race came from one origin, and that the varieties of it have been produced by the various influences to which man has been subjected. These are commonly included in the general expression, *climatic and other influences*. To be more particular, they are—climate, situation, food, clothing, customs, habits, state of civilization.

Too great prominence has been undoubtedly given to the influence of climate. Lawrence very justly remarks in his general conclusions in regard to the production of the varieties in man and animals, "that of the circumstances which favor this disposition to the production of the varieties in the animal kingdom, the most powerful is the state of *domestication*." This word, as he uses it, includes all those social influences, which as manifestly affect the animals which man domesticates as they do man himself. The analogy between man and animals in relation to the results of the influences referred to, will be spoken of more particularly.

That climatic and other influences do have a very great agency in producing the varieties, both individual and general, that we see on looking over the human family, no one doubts. The only question is, whether they have produced *all* these differences—whether, for example, they have occasioned that very wide difference that we see between the Caucasian and the Ethiopian. These limits will not allow us to go into a full examination of the influence of

these causes, and only a few points will be noticed in a very general way.

427. Color Affected by Climate.—That climate has a great influence upon the color of the race is proved by many clearly observed facts. Tropical heat always has a tendency to produce a black skin. This is shown very decidedly in the case of the Jews, who have preserved their characteristic features amid varieties of climate, and yet have their color altered.

Thus, while the Jew of the interior of Europe has a fair complexion and light hair, under the scorching sun of India his hair is crisped, and his skin is black. The evidence of the influence of climate is the stronger in this case, because the change from the original color has been twofold. For the original Jew in Palestine had undoubtedly a dusky skin and dark hair, upon which the temperate climate of the interior of Europe and the tropical climate of India have produced two opposite effects.

428. Circumstances Affecting the Form.—But in the varieties of the human race there are differences of form as well as of color. That the various influences to which man is subjected have a marked effect upon his physical form is universally acknowledged. We see this alike in individuals, families, and nations. Intellectual and moral influences manifestly have some agency in moulding the shape of the head in the individual. The differences which we so commonly see in the shape of the head between the intellectual and the ignorant, are not owing altogether to original difference of capacity, but in part to education.

The brain, like all other organs in the body, is influenced in its development by the degree of activity to which it is stimulated. It is not made an exception to this general law of development. Accordingly we find that depressing influences tend to make the top of the head, the cerebral part, small, and the forehead retreating, while the face, from the predominance of the sensual over the intellectual, is rendered relatively too prominent. The tendency of elevating influences is of an opposite character. And

such influences, thus operating in the individual, when repeated and accumulated from generation to generation, produce great and lasting results. It is thus that a race becomes either degraded or elevated. By a continuance and accumulation of influences it acquires either a good or a bad fixed character.

One class of causes effecting changes in the physical form has been mentioned, the influence of which is manifest. But there are changes seen, the causes of which we cannot clearly make out; and yet we know that they are occasioned by the varying circumstances in which man is placed. By the compound influence of many causes combined we continually see introduced differences in the shapes of various parts of the body. Family and national peculiarities are thus occasioned. The influences to which we have thus referred, some of which are little understood, are all those which Mr. Lawrence includes in the term *domestication*, which, as before said, he applies to man as well as to animals.

429. Marked Tendencies to Three Different Forms of the Head.—Dr. Prichard has pointed out three different types of form in the head, occasioned by three distinct classes of influences. One he terms the *prognathous* (a word derived from two Greek words meaning *before* and *the jaw*), in which the jaws project very prominently forward. This formation is characterized by the predominance of the sensual over the intellectual, the apparatus of the senses being largely developed, while the cerebrum is small, making the forehead retreating.

The tendency to assume this type is always in proportion to the action of the degrading influences. "Want, squalor, and ignorance," says Carpenter, "have a special tendency to induce the diminution of the cranial portion of the skull, and that increase of the facial, which characterize the prognathous type." It is seen most strongly marked in the negroes of the Gold Coast.

In the *pyramidal* type, as it is termed, the cheek bones are very broad, and the bones above are so shaped as to

give the top of the head a sort of pyramidal form. This type we see in those tribes that lead a wandering life—the nomadic races, as they are called.

The oval or elliptical form, which is seen so well marked in the Caucasian variety, is manifestly the result of elevating influences. These types are convertible into each other. Thus, the oval may be degraded into the prognathous, or the prognathous may be elevated into the oval. The latter change is seen in the Ethiopian, when in successive generations he is subjected to elevating influences, in his intercourse with the Caucasian. And it is interesting to observe that the form of the head is more readily changed than the color.

"Thus," says Carpenter, "in some of the older West Indian colonies, it is not uncommon to meet with negroes, the descendants of those first introduced there, who exhibit a very European physiognomy; and it has even been asserted that a negro belonging to the Dutch portion of Guinea may be distinguished from another belonging to the British settlements, by the similarity of the features and expression in each to those which peculiarly characterized his master's. The effect could not have been produced by the mixture of bloods, since this would be made apparent by alteration of color." In the same way is the pyramidal type convertible with the others. The pyramidal and the prognathous are often mingled together, by the influence of vagabond habits and degrading causes.

430. Insensible Gradations in Diversity.—The view thus given of the operation of influences in producing the varieties of mankind is strengthened by the fact that, as Humboldt says in his *Cosmos*, there are "many intermediate gradations in the color of the skin and in the form of the skull." If we look alone at the extremes in varieties of color and form, we are of course disposed to regard such great differences as marking a distinction of species. But when we see these varieties passing into each other by such insensible gradations, and at the same time observe the manifest influence of causes

upon these gradations, as in the cases referred to in the last paragraph, the evidence is clear to us that the varied influences brought to bear upon man are competent to produce the varieties of the race.

431. Fixedness of the Varieties.—But it is objected that, although climatic and other influences have a great effect, yet, so far as we can see, they only produce changes that approximate to those differences that mark the grand divisions of the race. They cannot, for example, be shown, from actual observation, to have effected the entire change in any length of time of any portion of the Caucasian race into the Ethiopian, and, on the other hand, of the Ethiopian into the Caucasian. It is objected, farther, that the peculiarities of the principal varieties of man existed in the early history of the race. This appears in relation to the Ethiopian variety in the figures found on Egyptian monuments. These show that the peculiarities of the negro race were as strongly marked nearly 5,000 years ago as they are now. This fixedness of character under such a variety of influences continued so long, it is claimed, indicates that the peculiarities were original, and not acquired.

In reply to both of these objections, your attention is called to a general fact, which is deemed very significant in its bearing upon the great point at issue. It is the fact that *when a variety is formed by any influences, either among plants or animals, it is apt to remain in spite of opposing influences.* It seems to be easier by far to produce a variety, than to bring it back to the character of the original from which it came.

432. Influence of Domestication both in Man and in Animals.—Domestication has been continually producing varieties in the animals that man has so largely appropriated to his service, and the varieties once produced commonly remain. And the same thing is seen in the varieties resulting so continually in the human race from the same class of influences. It is matter of common observation that family and national peculiarities

are apt to be perpetuated. And it is not merely from a continuance of the causes from which they result, for they are apt to remain even when strong counteracting influences are brought to bear upon them.

Now the causes which tend to produce varieties in the human race acted of course at the first, and during the first ages of the race were competent to produce the most prominent varieties. And the tendency to fixedness, which we see exemplified in so many ways in the varieties of both plants and animals, is sufficient to account for the perpetuation of such marked characteristics as those of the Ethiopian and the Caucasian.

The analogy then which is thus observed between man and the domesticated animals is a much clearer and stronger one than that which Professor Agassiz has attempted to make out between man and animals generally in regard to zoological districts. And the inference is a legitimate one, that the same influences that we see produce varieties in domesticated animals, are competent to produce the varieties in the human race, which are even less marked than some of those which we see in animals. Varieties are produced more readily and in greater numbers in animals than in man, probably because they have less power of resisting influences that act upon them. The varieties of some of the domesticated animals are very numerous.

The analogy drawn between man and animals in regard to zoological districts is weakened by the consideration that there was no necessity for man's being created in different localities, because he can migrate so easily from one country to another. The necessity existed in regard to plants and animals, but not to the same extent in all. Migration is easier in the case of some than in the case of others. And this difference seems to have been acted upon by the Creator.

Accordingly, the evidence is quite conclusive, that those animals which have been so universally appropriated by man to his service, have been diffused from central points and have gone with man, instead of being created in many

localities. This being the case, it is hardly to be supposed that man, who is capable, through his ingenuity, and skill, and daring, of going every where, would be unnecessarily created in different pairs at different points on the earth's surface.

433. New Causes Occasionally Introduced by the Creator.—But suppose that, in view of all the evidence, we should come to the conclusion that the climatic and other influences are not the sole causes of the differences in the races, are we of course driven to the admission that, as Agassiz and others teach, there must have been created at the first, several, we know not how many, different pairs in different localities? By no means. We are not to forget that the Creator, besides using influences of which we have no knowledge (which he is continually doing), can effect new combinations of the causes already existing, or introduce into operation entirely new causes. That he is from time to time evolving new results in one or the other of these ways, or both of them, is manifest.

The very common notion, that at the creation all the causes which have produced all the phenomena that have been observed to the present time were then set in operation, and have been left to work out their results, seems to be contradicted by many facts. Most of the causes then set in operation, it is true, have been at work ever since. Unless this were so, nature would not exhibit the regularity which it now does, and calculations could not be made with such definiteness as to its processes from knowledge gained by experience. But changes and irregularities sometimes occur which must have been the result of new causes. A few examples only will be given.

The age of man before the flood was much greater than it has been since. A change was effected at that period. It was not a mere arbitrary change, but such a change in the very character of the human system, that its capability of resisting the tendency to decline was greatly reduced in the period of its continuance. It was not a change resulting from the influence of deteriorating causes, for in that

case it would have been less suddenly induced. To effect this change some new causes must clearly have been brought to bear upon the system, making it in the post-diluvian a different system in some important respects from what it was in the ante-diluvian.

Take a fact of a different kind, indicating a similar change of agency. New diseases from time to time appear. This could not occur without either entirely new causes, or new combinations of elements heretofore existing. That very definitely marked disease, the small-pox, we have the best of evidence, was not known to the ancients, but is comparatively a modern disease. It is impossible to conceive of its being introduced without some new cause of a very definite character.

Take now another fact of a widely different kind from either of those noticed. The earth is marked all over with signs of great convulsions that have occurred since its creation. It has been supposed till recently that these signs all refer to that great event described in the Bible, the Deluge of Noah; but geological researches have demonstrated pretty clearly that they point in part at least to other previous convulsions. Now these convulsions are not to be reckoned as a part of the regular order of nature. They could not have resulted from the *ordinary causes* that act continuously. New causes must have been introduced at the time, to produce these unwonted results.

It matters not to the argument above indicated, whether the new results that are occasionally developed, come from a direct agency at the time, or come from a chain of causes set in operation a long time before. The results are new results, and come from causes or combinations of causes which differ from those that have produced the ordinary and regular results which we witness from day to day or from year to year.

Now in like manner can we suppose, if it be necessary, that the Creator produced the varieties of the human race by adding other and new causes to the ordinary influences to which man is subjected. This is a much more probable

supposition than that of the advocates of the multiple origin of the race.

For besides accounting satisfactorily for the facts, and at the same time being consistent with the record in Genesis, it is more clearly supported by analogical facts than the supposition (for it is mere supposition) that the human race was created in different localities. And farther, this supposition avoids difficulties which attend the other. For, if we suppose that the race came from different pairs, it would be difficult to decide how many pairs there were. Such are the variations of the race in different localities that there would be much disagreement as to the number of the representative pairs, and their distinguishing characteristics.

But it may perhaps be said in objection, that we are supposing a miraculous interposition. Whether it may rightly be termed such will not be considered; but it is just such an interposition, or rather, direct agency, as is affirmed by the advocates of a multiple creation, *differing from it only in the time of its occurrence.*

They suppose the direct agency of God to be put forth in creation at different points, whether at different times they do not say, and this is really quite immaterial; and we suppose the same direct agency to be put forth, but in a less marked manner, to produce a change in what has been already created. In supposing the direct agency of the Deity at all, we go beyond mere physics; and he surely has the power to put forth this agency at such times as he pleases.*

* There seems to be in the minds of some naturalists a great reluctance to admit at all the direct agency of the Creator, whether it be exerted in consonance with the order of nature which he has established, or miraculously in opposition to it. And they would smile skeptically at what they would deem the simplicity or superstition of Hugh Miller, in referring some narrow escapes which he has had, in pursuing his geological researches, to a particular Providence. The relation of the agency of the great First Cause to second causes, it is true, is a mysterious subject; but it implies no disposition to fathom what is unfathomable if we assert that the facts are far from warranting us in the belief that this agency has not been exerted since the period of the creation, but confined itself to that time.

But the supposition made above is not needed. The regular, continuous, natural causes, which have ever operated upon man, have been competent to produce all the varieties of the race. And this supposition was only suggested as a consideration for those who fail to see that these causes have been thus competent; it is a more probable supposition than the one offered by Agassiz and others to meet the difficulty in the minds of such persons.

434. *The Testimony of the Bible to be Received as Evidence.*—Thus far this subject has been treated chiefly as one of natural history and physiology. But is the testimony of the Bible not to be received as a part of the evidence? Is the question to be decided wholly on considerations and facts drawn from natural history and physiology? This seems to be the view of some naturalists, though the great majority of them are disposed to admit the statements of Scripture as evidence.

It is true that the Bible does not purport to be a philosophical book. Its language is based on the principles of common and not scientific usage, and is so to be interpreted. And it should be thus interpreted in relation to the subject before us. Its statements on this subject are of the most explicit character. It purports to give an account of the origin of the race, and portions of its history. It ascribes the corrupt character of the race to a fallen parentage. This connection of the general corruption of the race with the fall of its original pair, however divines and philosophers may differ in accounting for it, is recognized as a fact throughout the whole book of revelation. The testimony is definite, and is not to be mistaken.

The question is, whether it be valid testimony. And if the Scriptural record be established, as it is abundantly, by both internal and coincident evidence, its testimony in regard to the origin of the race is to be received by scientific men. It can not be set aside by any mere presumptive and analogical evidence drawn from physiology and natural history. If actual facts be proved inconsistent with the Mosaic history, as properly interpreted, they will of

course bring discredit upon that history. No immunity against a strict investigation is to be claimed for the Bible. But there is no fear of such an issue; and it is to be remembered that mere analogies are not facts, and are not to be deemed as having much force, especially when there is a question in regard to their value in comparison with other analogies that point to an opposite conclusion.

CHAPTER XX.

LIFE AND DEATH.

435. Life, though Various in its Manifestations, in some Senses always the Same.—Life is very commonly spoken of as being one thing, although its manifestations are exceedingly various in their character. In the simplest growths that we see, both in the vegetable and in the animal kingdoms, the operations of life are in some respects very different from the complicated processes that we witness in the human structure, which has been the subject of your study in this book. And yet, as you have seen in the Chapter on Cell-Life, life in these apparently opposite cases is essentially the same. It is the same in its origin. It begins always in a single cell, whether the living being is to be great or small, simple or complex, a plant or an animal, a creature of a day, or a being destined to immortality.

Why it is that from a simple cell the vital force, as it is termed, can evolve such a range of diversified results as we see in all animated nature, is one of the great mysteries of the Creator. As we see in the springtime a bud upon a tree unfold itself gradually, and develop to us successively leaves and flowers and fruit, it fills us with wonder when we reflect how much has come from that little bud; but when we go farther, and think of the whole tree as having come from a single cell, so small that it can be seen only

by the microscope, the mystery appears passing wonderful. And it is a still greater mystery, when a complicated animal organization is looked at as having been developed by the vital force, alike with all other living things, through a single cell as its origin.

Not only is life always the same in its origin, but it continues essentially the same in its processes. All the various forms which it produces, both in the vegetable and in the animal world, are built and kept in repair by cells. All the functions, too, are carried on through the same agency. The secretions and excretions are effected by constant successive creations of numberless cells. Even the intellectual operations in the mind of man are dependent upon cells so long as the mind is connected with the body. In thinking, as well as in muscular motion, cells are worn out, and must be replaced by other cells, which are continually supplied by the vital force.

436. Difference between the Vital Force, and Heat, Light, and Electricity.—Life being thus wonderful in its operations, the inquiry arises, what can this mysterious agent be? With curious eye we watch its workings, but although we can learn some of its laws, its nature eludes our search. Then pressing the microscope into our service, we trace it back to its hiding-place in a minute round cell containing a fluid; but simple as this prison is in which it is confined, it is more of a mystery than ever. The vital force, which begins here, and, enlarging more and more the sphere of its operations, develops gradually the simple or the complicated living form, as the case may be, has been classed by some with other forces, the nature of which we do not understand, as heat, light, and electricity. But it differs from them entirely in some important points. While they act in connection with matter generally, both organized and unorganized, vital force is seen acting only in organized substances. While they diffuse themselves through all kinds of matter with more or less rapidity, the vital force has no power of diffusion, but is confined within certain limits. These limits differ

in the different living substances. The vital force has the power of appropriating matter to itself within these limits. It does this by assimilation. It has then the power of extension to a limited degree; while the other forces mentioned have the power of diffusion, in some respects limitless.

Another difference is this. While these forces, light, heat, and electricity, are lessened in power by being diffused, vital force is not lessened by extension. Heat, for example, if diffused is lessened at the point of its diffusion; but life is as energetic at its starting-point after its extension as before, and even more so. It is, so to speak, self-generating, while the other forces are mere products. The vital force stands peculiarly alone in this respect. The effects, too, which this force produces, as it lays common matter under contribution, and fashions it in such diversified forms, have an infinitely wider range of variety than the effects of the other forces.

437. Life in Blood.—We can thus trace the differences between the vital force or principle and other forces, but we can not, as before said, discern its nature. We know not whether it be one thing. It is convenient to speak of it as being so. But we know not but that it may be a compound of endowments, or tendencies imparted to matter, and varying with the various forms of living substances. Some have supposed that the vital principle resides chiefly in the blood, and that this is the meaning of the passage in the Bible, "the life of the flesh is the blood." That the blood has some vital properties is certainly true. These properties are communicated to it as it is made from the food, and fit it to be the material for the construction and repair of the organization. And it is simply the fact, that the blood is the common material out of which all the diversified parts of the living structure are made, that is recognized in the language of Scripture on this subject. The same fact is embodied in another form in the remark of the French physiologist, that the blood is *chair coulante*, or running flesh.

438.—Vital Laws Control the Chemical and

Mechanical.—When the vital force appropriates to itself common matter in assimilation, it takes it away in part from the operation of certain forces which have had entire control over it. As long as it is common dead matter, it is wholly subject to the laws of mechanics, and of chemical action. But when it becomes organized living matter, the laws of life take possession of it.

The laws of chemistry and mechanics are not, it is true, annulled in relation to it. They still exert their influence, but under the control of vital laws. The force of gravity acts continually upon the body; but the living muscles are much of the time acting in direct opposition to it. The blood circulates on hydraulic principles; but the vital force furnishes the motive power, and keeps the blood from becoming solid and stopping up its channels. Chemical changes are going on in the stomach, the lungs, and at every point in the capillary circulation; but they are modified, controlled, by the vital principle, and are properly termed chemico-vital processes.

The human body is made of materials that are exceedingly prone to chemical decomposition, and the degree of heat which is maintained is such as to favor this result; but the vital force not only holds the chemistry of the system in abeyance, but even presses it into its service. When life is destroyed, the laws of chemistry assume their full sway, and the process of decay begins.

The very agencies which served, while under the control of the vital principle, to maintain the living organization, now acting alone, run riot, and work its destruction. Thus, that powerful agent, heat, existing in the body at the point of 98° , is necessary to the carrying on of the processes of life; but let life be destroyed, and the maintenance of this degree of heat would ensure a very rapid putrefaction. So, too, a degree of heat which would rapidly putrefy a dead egg by quickening the chemical changes, would actively stimulate in a living egg those curious vital processes that produce at length the bird. During incubation the egg of the hen is kept for three weeks at a heat of 105° , and yet

when the chicken is hatched all of the yolk that is left is unchanged. A dead egg would soon putrefy under such a temperature.

439. Change always attends Life in Action.—The vital force exhibits its controlling power in an extraordinary manner in connection with that great force of nature to which reference has just been made. Heat is very diffusive, and is exceedingly liable to change from varying circumstances. And yet the vital force maintains the heat of the body quite uniformly at one point, although the agencies which tend to vary it are very numerous and effective. The production of heat in the system is a chemical operation, but the vital principle regulates the quantity in the body very accurately, by providing for its escape in various ways, and perhaps by curtailing in some measure its production.

Continual changes are effected by the vital force in every part of the body. In one sense death may be said to be taking place constantly, while life is as constantly generated, as the useless particles are separated and taken away, and the new ones are deposited in their place. While these changes are going on the vital force so operates as to maintain the peculiar shape and plan of every part, even during its growth. And as we look abroad over all the diversified forms of animated nature, the accuracy with which this force works in the prescribed mould of each is very wonderful.

440. Life Sometimes Dormant.—While the vital force is in action there is constant change; but sometimes it is dormant. A seed in its quiescent state has life in it, ready to be waked into action by the proper excitants, air, warmth, and moisture. Seeds that were found in the excavations of Pompeii have shown that they retained their life during all this time, by shooting forth their germs as soon as they were exposed to these natural excitants of their growth.

One of the most interesting cases of this kind is related by Dr. Lindley. "I have now before me," he says, "three

plants of Raspberries, which have been raised in the gardens of the Horticultural Society, from seeds taken from the stomach of a man whose skeleton was found thirty feet below the surface of the earth, at the bottom of a burrow which was opened near Dorchester. He had been buried with some coin of the Emperor Hadrian, and it is probable, therefore, that the seeds were sixteen or seventeen hundred years old."

A similar dormant condition of the vital force exists in a greater or less degree in the state of hibernation. So, also, in cold climates, life is throughout almost the whole vegetable world dormant during the period of winter, to wake to greater energy from the stimulating warmth of spring. In the human body, with the exception of some few very rare cases, life is always in an active state. Some portions, however, of the system are a part of the time dormant for the purpose of rest and repair.

The brain and the muscles sleep; but during their sleep life is busy in the formative vessels, repairing their energies, and we may say, their textures also, which have been wasted by their labor. It is a very wonderful attribute of the vital force that it can, as in the case of the hibernating warm-blooded animals, stop all its active operations, without damage to the machinery of life, and with such facility resign itself to a state of temporary inactivity.

441. Mysterious Connection of Life with the Soul.—The most mysterious of all the circumstances in regard to the vital force is its connection in man with the immortal soul. The life and the soul are so intimately connected that some have considered them to be the same. But they are two distinct forces. They are in some measure indeed antagonistic to each other. For the soul, in using the machinery of the nerves and muscles, occasions a wear and tear of the structure, which it is the office of life with its numberless cell-laboratories to repair.

The soul and the vital principle are both present in all parts of the system, but not in the same sense. The vital principle is seen equally at work every where. It has no great

central organ from which it sends forth its influence. But the soul is especially connected with the brain, and by means of the complicated nervous connections of this organ, it affects and is affected by all parts of the system. Its influence is thus an all-pervading one. Every point of the living organization has thus a sort of telegraphic communication with the immaterial soul.

But there is another view of this connection of the soul and the vital principle. The soul is developed in and with the living structure. It is not created by itself and put into the body as a tenant. Its powers are developed while the vital force develops the powers of the physical organization. The two processes go on together. Nay more, the development of the soul is in a measure dependent upon the development of the body. The vital force exerts a manifest influence upon the soul's growth. As it prepares the organs for the use of the soul—those organs by which it acquires knowledge from without, and thus procures the stimulus and even the material for its growth—whenever the vital force fails to construct these organs properly, the powers of the soul are not well developed. This we see exemplified in the idiot.

In this intimate connection of the soul with life we find a great mystery. Life, a force belonging to mere matter, an endowment of it, or a compound of its endowments—life, that builds up all organized substances, the humblest and simplest vegetable growth as well as that most complex of all living structures, man—life, that so soon perishes in the noblest of its works that it is likened to the dissolving vapor—is made by the Creator an agent in developing an immaterial principle or being, that is to survive the dissolution of the structure in which it is generated, and is to live forever. Strange that the immortal should be thus produced in the mortal—that the unchangeable and imperishable soul should be thus developed in such intimate connection with the changeable and perishable body. It is a mystery which we can not fathom.

442. Natural Limits of Life Decay.—The vital

force, that is so busy in building and repairing so long as it lasts, has in all cases its natural limit; and in the case of the human system it seldom fully reaches this limit. The diversified, and complicated, and beautiful structures which it evolves, if saved from accident till the natural period of decline comes, lose their vigor and beauty, and at length die and are given up to the action of the common laws of chemistry, which the vital force has so long resisted and controlled. The structures then decay, and the particles are dissipated, perhaps to be united again to other structures.

443. *Systemic and Molecular Death.*—The death of the body is not ordinarily complete at the moment when what we term death occurs. Though as a whole, as a system of organs, the operations of life are at an end, yet there is some degree of life in some parts, and there may be in all parts of the body. The beard and nails even, may grow. Some of the organs may secrete their fluids—the liver its bile, and the stomach its gastric juice. Some of the properties of life, too manifestly, still remain. The irritability of the muscles, which is strictly a vital property, as it never belongs to common dead matter, still appears on the application of excitants. It was the contraction of the muscles in the leg of a dead frog on the accidental application of a stimulus, that led Galvani to his grand discovery. And it is through this vital property that the culprit who has been hung can be galvanized into apparent life.

Death, then, may be said to be of two kinds—*systemic*, that is, the death of the body as a whole, a system of organs—and *molecular*, that is, the death of the individual molecules or particles which compose the body. Death can be said to be complete only when the laws of life have resigned their power over these molecules, and the laws of purely chemical action have taken their place. When this change occurs, the process of decay, which is strictly a chemical process, begins.

444. *Death beginning in the Heart and in the Lungs.*—If a large quantity of blood be lost, so large as to result fatally, death in this case obviously begins in the

circulation. The heart not being supplied with the quantity of blood that usually flows through it, becomes more and more feeble in its action, till it at length ceases to beat. When a large aneurism bursts, it is the sudden drain from the circulation that destroys life.

Any thing which to any great extent prevents the air from entering the lungs may cause death to begin in the *respiratory system*. This may be done by three classes of causes. 1st. Causes that act upon the large air-passages. Examples of this class of causes are strangling, smothering, drowning, &c. In croup the principal cause of death is the prevention of the free passage of air through the wind-pipe into the lungs.

2d. Causes which act upon the walls of the chest. If a bank of earth fall upon a man, though it leave his head clear, so that the air-passages are unobstructed, he can not breathe, because his chest is held as if in a vise. A man came near dying from this cause who was having a cast taken of the upper part of his body. If the muscles of respiration were to be paralyzed, death would ensue, just as it does when they are prevented from acting by other causes.

3d. Causes acting upon the lungs. Disease may occasion an amount of obstruction in the very substance of the lungs sufficient to cause death. It does so by preventing the introduction of the air into the minute air-vessels, where the air revivifies the blood. The obstruction is just as effectual in this case as it is where it occurs in the large air-passages.

445. Death beginning in the Nervous System.—When death occurs from a blow upon the head as the immediate result of the shock, we have an example of death beginning in the *nervous system*. But the cause may act upon this system in some other quarter. A blow at the pit of the stomach, for example, may so shock the whole nervous system as to stop at once the operations of life. Some poisons, too, as opium, destroy life by their influence upon this system. Very extensive burns give a shock to the nerves from which they do not rally. The same can be said of other injuries when there is no recovery from the

first shock. Powerful medicines, improperly given in cases of disease disposed to prostration, may depress the nervous system to a point from which it may never revive. Cold destroys life mostly by the numbing, paralyzing influence which it exerts upon the nerves.

Though we thus classify the modes of death, in the great majority of cases death is a complex event, resulting from a concurrence of causes. It is so even when the disease is not of a complicated character. Take, for example, a case of pure uncomplicated consumption, in which all the organs but the lungs are in a healthy state to the end. The whole system becomes at length exhausted by the disease. If this exhaustion alone be the cause of death, then we may say that it is an example of death beginning in the nervous system. But if the obstruction in the lungs to the admission of air in the air-cells be the cause, it is a case of death beginning in the respiratory system. Generally in such cases death results from the two causes combined, and it is often difficult to determine which is the more prominent cause.

446. *The Signs of Death.*—The signs of death are so clear that there is, with very few exceptions, no mistake in regard to the occurrence of the event. The stories that are related about burying alive are most of them unfounded. The apprehensions created by them in the minds of some persons have led them to insist that no body ought to be committed to the grave till the most infallible sign of death, putrefaction, has appeared. We should wait for the appearance of this sign in all cases in which there is a shadow of doubt. But the cases are exceedingly rare in which we cannot determine the reality of death long before this sign shows itself. Our decision is not made up, it must be observed, merely from the signs of death.

All the circumstances of the case are taken into view—the disease, its progress, its symptoms, and the events of the last hours of the patient. With this evidence before us, we absolutely know, in all ordinary cases, that death has occurred when the respiration and the circulation have ceased. And in the exceedingly few cases in which there is

any reason to doubt on that point, there is always something which will attract the attention and excite the curiosity of some one, unless there be stolid indifference and the most absolute lack of intelligence.

In such cases there is always something strange—the circumstances attending the cessation of the respiration and circulation are singular, and the signs of death are not complete and in their proper order of succession. Whenever there is for these reasons any doubt as to the reality of the apparent death, the strictest watch should be maintained till the signs of commencing putrefaction appear. With this simple rule of prevention burying alive need never occur.

The investigations of physiology, as you have seen, end with the death of the body. It can give us no light on the question as to what may be beyond this life. Although the physiologist studies the human structure not merely as an organization instinct with life, but also as the wonderful machinery through which a reasoning soul acts and is acted upon in this state of being, yet, as a physiologist, he knows not that the soul survives the death of the body.

He knows not but that it is a mere endowment of matter, as life probably is, and so perishes in the hour of dissolution. He may indeed conjecture that the exalted faculties which are in this world susceptible of such high cultivation, instead of being destroyed with the body, are destined to still farther development in another state of existence. But what is mere conjecture to him as a Physiologist, is made fact to him as a Christian. The eye of his faith sees an immortal spirit rise from the dying body, and he realizes the truth of the sublime declaration, that death is swallowed up in victory.

QUESTIONS.

CHAPTER I.

1. In what respect are a crystal and a plant alike? How do they differ in the modes of their formation? What different offices do the organs in a plant perform? What is meant when we call the plant an *organized* substance, and the crystal an *unorganized* substance? Do the organs in the plant act wholly on *mechanical* principles?

2. Or on *chemical*? What principles control the mechanical and the chemical? What two classes are there of organized living beings? How do they differ as to the complex character of their organization? Under what two grand divisions do you class all the substances of the material world? How do plants and animals differ from minerals as to the parts of which they are composed?

3. What is assimilation? Explain it as it takes place:—First, in the plant, and secondly, in the animal.

4. How do organized and unorganized substances differ as to permanency? Point out the mode and the extent of the change that occurs in the organized. Why is there more change in animals than in plants? How can minerals be changed? Are they productive, as animals and plants are?

5. Contrast organized and unorganized substances in regard to change in the phenomena that you see in the world around you. How do organized and unorganized substances differ as to regularity in form?

6. What does irregularity in the unorganized arise from? How does the law of regularity operate in organized substances? In which is the regularity the most wonderful, the organized or the unorganized, and why?

7. Give the four reasons assigned:—First, as to change; secondly, as to variety of form; thirdly, as to its continuance from age to age; and fourthly, as to its preservation in the midst of a certain range of irregularity. Exemplify the last point by reference to the human countenance. How is the law of regularity exemplified in the two halves of the body? Mention some organs which are destitute of this symmetry; mention also some animals that do not exhibit it. What

is the distinction between organized and unorganized substances as to limit of size?

8. How do organized and unorganized substances differ as to their structure? How do they differ as to the number of elements of which they are composed? What are the four principal elements of organized bodies? Which one of these is solid? In what form are the other three? How many elementary substances are there in the material world? How many of these are found in plants and animals?

CHAPTER II.

9. Point out the difference between the plant and the animal as to locomotion. How does this difference make it necessary that the animal should have a stomach?

10. Trace the analogy between the stomach in the animal and the roots in the plant. What is the difference between most animals and plants as to central organs? What is their difference as to the effect of mutilation upon them? What is the distinction between animals and vegetables as to sensation and spontaneous motion? Have all animals consciousness and thought? Name some exceptions to the distinction as to locomotion. What is the difference between the motions of such plants as the sensitive-plant and catch-fly, and those of animals?

11. Make the comparison in relation to the hydra, which describe. What part of the structure of animals is peculiar to them. Has this structure ever been discovered in any plant? Why ought we to be able to discover it in the sensitive-plant and catch-fly, if it were the cause of their motions?

12. Is the nervous system necessary to the carrying on of nutrition? What are the functions of *organic* life? What of *animal* life? What is the order of action in the nervous system? In what respect is this order not observed in some cases?

13. What is the distinction between animals and plants as to their chemical composition? In which is carbon the characteristic element, and in which is it nitrogen? From what organs in animals is carbon thrown off? In what organs in plants is it absorbed?

CHAPTER III.

13. How is man commonly classed in the animal kingdom? On what ground can the classification be claimed to be correct? Does this classification recognize at all the essential distinctions between man and other animals.

14. What are those distinctions? What bearing has man's immortality on this subject? Is the difference between man and other animals like that which we see between different animals?

15. Is it a mere difference of *degree*? What notice should the naturalist take of the difference? What is the distinction made in the common classification between man and such animals as apes and monkeys? Can these animals be properly said to have four hands? How do the hands which they are said to have resemble the hand of man, and how do they differ from it?

16. State some particulars in which the structure of man differs from that of the inferior animals.

17. What relation have the peculiarities of man's organization to his mental peculiarities? Why is it important that the essential distinctions between man and animals should be prominently taught?

CHAPTER IV.

17. Of what two parts is bone composed? What are the proportions of these parts in childhood—in adult age—and in old age? How can you obtain these parts separate from each other?

18. What is the animal part of bone? What relation does this sustain to the mineral part? What is the arrangement of the two parts of bone in the very young child? What is true of the skeleton of many fishes? Of what are cartilages constituted? What two different purposes do the bones fulfil?

19. In what two forms is bony substance deposited? How are these arranged in the flat bones? How in the long? How are both lightness and strength secured in a long bone—first, in the body of the bone, and then in its ends?

20. Why are the ends not made like the shaft? What is the marrow of the bone? How is a bone nourished? What is the *periosteum*? Do arteries enter the solid substance of the bone? Describe the manner in which circulation is carried on in every point, as shown by the microscope. What fluid circulates in the minute channels in bone, shown to us by the microscope?

21. What is said of the sensibility of bone?

22. Give a general description of the skeleton, noticing the variety of shape in the bones, and the purposes which they answer. How many bones are there in the head? How many of these belong to the face? How many to the cranium? Describe the latter, as represented in Fig. 6.

25. Why is the box (as the cranium may be called) holding the brain, composed of so many bones?

26. Describe the structure of the principal bones of the cranium.

What is the difference between the joinings of the outer and those of the inner tables of these bones? What is the reason of this difference?

27. How are the principles seen in the construction of domes illustrated in the cranium? Of what bones is the dome of the cranium made up? Describe the different ways in which strength is secured around the base of this dome.

28. Describe especially the arrangement between the parietal and temporal bones. When violence is inflicted upon the head, what is the direct cause of the injurious effects felt by the brain? On what principle do the guards of the brain defend against this cause of injury?

29. Mention now in their order the different textures through which the vibration of a blow must pass before it reaches the brain, pointing out their agency in lessening the vibration. What arrangement is there of the lower part of the frontal bone as a special guard against injury at that point?

30. How is the side of the head, so peculiarly exposed to violence, especially guarded? What other organs, beside the brain, are protected by the cranium? Describe the arrangement of some of the bones of the face.

31. Describe the cavities of the nostrils, and the sinuses connected with them. What is the object of the great extent of surface in these cavities? Describe the lower jaw.

32. How many distinct structures are there in the teeth? What is their arrangement? How does a tooth differ from a bone?

33. What is the reason for this difference? What is the necessity for having a second set of teeth? Describe the hyoid bone, its position, and its connections.

34. Mention other bones which, like this, are not directly connected with the bones of the skeleton. Of how many bones is the spinal column composed? Acting as the great pillar of the body, what does it support? What is the pedestal on which it stands, and in what manner is this pedestal made firm? While this column is thus firm, it needs to be flexible—how is this accomplished? Notice its different degrees of flexibility in different portions of it. Why is there so little motion in that portion that supports the framework of the chest?

35. Besides serving as a firm pillar and a flexible chain, what other purpose does the spinal column fulfil? Describe a vertebra.

36. By what are the vertebrae bound together? Describe the canal in this column for the spinal marrow. What is the arrangement for the nerves that pass from it? How are the cartilages arranged?

37. What two purposes do they subserve? What is there in the shape of the spinal column that acts as a safeguard against shocks to

the brain? What are now the three objects secured in the structure of the spine?

38. Describe the contrivance at the top of it, as represented in Figs. 14, 15 and 16. Compare this with the mounting of a telescope. What is the difference in the two cases?

39. By what arrangement is the freeness of motion in the neck of birds made consistent with the security of the spinal marrow?

40. What is there peculiar in the spinal column of quadrupeds? What is the *paxy-waxy*? How are the vertebrae of fishes constructed and arranged?

41. How is the great flexibility of the spine in reptiles secured? How in the neck of the giraffe?

42. Describe the arrangement of the breast-bone, the collar-bone, and the shoulder-blades. What is the use of the collar-bone, and what are its variations in different animals? How does the shoulder-blade differ from all other bones in the body?

44. Why is the socket of the shoulder-joint so shallow? Describe the arrangement of the radius and ulna, and the manner in which such free and varied motion is given to the arm. Describe the three parts of the hand?

45. Describe the ligaments that bind the bones of the hand together.

46. What is the principal object aimed at in the construction of the lower extremity? What in the upper? Describe the thigh-bone.

47. What is the patella? What purposes does it answer? What part of the foot is formed by the *tarsus*? What part by the *metatarsus*? How many bones are there in the toes? How many in the whole foot? What object is secured by having so many bones in the foot? Why is the foot arched?

48. Describe its movement in walking. With what are the ends of the bones tipped, and why? What is the arrangement of the membrane that lines the ends of the bones?

50. What contrivance is there in the knee-joint, and in the articulation of the lower jaw?

CHAPTER V.

50. Give the summary in regard to the action of the muscles, and their nervous connections.

51. What are the tendons? What is said of the relation they bear to the muscles—their shape—their mode of union with muscles and with bones—their strength—and their size?

52. How are the muscles and tendons arranged in reference to con-

venience and beauty? Illustrate by the arm and the hand. Illustrate the application of the first kind of lever in the action of muscles.

53. So also of the second kind.

54. And of the third kind. Which kind is most frequently used in the body?

55. What two different objects are aimed at in the application of these two levers? Illustrate by examples of the second kind of lever.

56. Illustrate the same by examples of the third kind. What is the difference between the motion of the forearm on the arm, and the motion of the lower jaw, in the application of the principles alluded to?

57. Show how quickness is secured at the sacrifice of power in the case of the biceps muscle, as illustrated in Fig. 33. Under what mechanical disadvantage do most of the muscles act, as represented in Fig. 34.

59. Show by this figure how quickness of movement is gained in this case. Why is the muscle, the deltoid, whose action is represented in this diagram, so large?

60. How is the mechanical disadvantage, which thus results from the oblique action of the muscles, in part obviated? Illustrate by Figs. 35 and 36. Describe the agency of the patella in this respect.

61. To what extent is the pulley used in the arrangement of muscles? Show the application of the pulley, as seen in the ankle.

62. Describe the pulley arrangement of the *digastric* muscle. What is the necessity for such an arrangement?

63. What other office does this muscle perform, besides drawing down the lower jaw, and how does it do it? Describe the muscles that move the ball of the eye.

64. What is said of the actions of opponent muscles?

65. Give some examples of the *tonic contraction* of muscles. What is the cause of wry neck, and of squinting? Illustrate the compound action of muscles by Fig. 32. How does variation in the *degree* of the contraction of muscles affect the variety of motion? What organ peculiarly exemplifies variety in muscular action?

66. Give a general description of the muscles of the body as exhibited in Figs. 41 and 42.

70. What other parts besides the bones are moved by muscles? How are the muscles arranged in reference to convenience and symmetry? Describe a peculiar arrangement of tendons and muscles in the sole of the foot. Describe the arrangement of tendons represented in Fig. 43.

71. Describe the operation of the toggle-joint. Give examples of the application of this operation in the action of muscles.

72. How many muscles are there in the hand and arm? What is said of the extent of the variety of their action? What is the muscular sense? Illustrate the operation of it in various ways.

CHAPTER VI.

74. By what alone are thought and feeling expressed? By what mode of muscular action are thought and feeling mostly communicated? What relation has writing to this mode of communication? Describe the muscles of the face with the action of each as exhibited in Fig. 45.

76. Describe the muscles about the mouth, as shown in Fig. 46.

77. In what way is the expression of the face made the same in its two halves?

78. Explain the agency of various muscles—the frontal—the corrugator supercilii—the superbus. What is the action of the muscles in quiet sorrow?

79. Is there commonly any one muscle devoted to the expression of any one emotion or passion? Does the same muscle often take a part in the expression of various emotions? What is their state in the expression of a calm pleasure? Illustrate the agency of the muscles of the eyeball in expression. What is said of the action of the oblique muscles? Why is the intoxicated man apt to squint and see double? Why does he raise his eyebrows in the effort to keep his eyes open? What other parts besides the face are brought into action in the language of the muscles.

80. What is said of the action of the rest of the body in expression? What muscles of the body sympathize most with those of the face in expression? Give examples in illustration. Explain the expression of the countenance, as seen after death.

CHAPTER VII.

81. Give a summary of the processes of digestion.

82. Of what substances is the body of a tooth composed, and how are they arranged? What are the different shapes of teeth, and for what different purposes are they fitted? How do the teeth of carnivorous animals differ from those of the herbivorous? How does the motion of the lower jaw differ in the two classes? What is the shape of the teeth in the insectivorous? What in the frugivorous?

83. What is the peculiar arrangement of the enamel in the teeth of the herbivorous, and for what purpose? What can be inferred about an animal from an examination of his teeth? Why is man said to be an *omnivorous* animal?

84. Why are his tearing teeth less in length and in power than those of carnivorous animals? What has the common whale instead of teeth? What is the purpose of the arrangement?

85. What supplies the place of teeth in birds? What is the use of the saliva? Describe the situation and arrangement of the glands that supply this fluid.

86. How much saliva is secreted by the salivary glands during a meal? Why is more saliva than usual needed when one is speaking? What effect does motion of the mouth have on the secretion? How are these salivary glands affected by tobacco-chewing? Explain the influence of sympathy in the secretion of saliva. What are the two kinds of fluid secreted by the salivary glands, and what is the purpose of each kind?

87. Describe the various parts engaged in the act of swallowing, as represented in Figs. 54 and 55.

88. Describe the arrangement of muscular fibres in the cesophagus.

89. What is the character of the gastric juice? By what is it formed?

90. Describe the appearance of the mucous membrane of the stomach, as seen by Dr. Beaumont, in the case of Alexis St. Martin. To what is the amount of gastric juice proportioned? What is the effect of stimulating the stomach to too large a secretion of it from day to day? What is the nature of its action on the food? How is the application of it to all portions of the food secured? Describe the arrangement of the muscular fibres of the stomach, and the manner of their action.

91. What is the chyme? What is the arrangement of the valve called the *pylorus*? When is the pylorus especially in action? If there be difficulty in digesting the food, what is the effect on the action of this valve? What is the true character of the process?

93. What is the consequence if fresh food be introduced into the stomach while the process is going on? Why is the practice of eating between meals a bad one? Why does eating fast, do harm? What effect has great variety in food? How does exercise affect digestion? Relate the experiment with the two dogs, and state what it proves.

94. What shows that hunger does not arise from emptiness? What that it does not arise from the irritation of the gastric juice? What is the *cause* of hunger? What is the *seat* of the sensation? Upon what does the degree of hunger depend? What must be the state of the stomach to have this sensation exist?

95. How do mental impressions sometimes destroy the sensation of hunger? What is the *cause* of thirst? Where is its *seat*? Describe the arrangement of the digestive organs as seen in Fig. 60.

96. What are the uses of the mesentery?

97. Where are the bile and the fluid secreted by the pancreas mingled with the chyme?

98. What is one of the offices which they execute? What is the chyle? What are the lacteals? What glands do they enter? After

passing on from these glands, into what duct do they empty the chyle ? What is the size of this duct, and where does it pour its contents ?

99. Describe the operation of the suction power at the mouth of the thoracic duct. What becomes of the chyle thus forced into the blood ? What is the general rule by which the variation in the digestive apparatus in different animals is governed ? Exemplify by a comparison between herbivorous and carnivorous animals. What is the length of the alimentary canal in the lion ? What in the sheep ? What in man ? In what animals is the stomach most complicated ?

100. Describe the apparatus of digestion in the sheep, and its successive processes. Which of the four cavities in the sheep's stomach is the real stomach ? Into which cavity does fluid matter always go ? What is the arrangement when the animal is suckling ?

102. Describe the digestive apparatus of birds as exemplified in the turkey. What circumstances govern the variation of the digestive organs in different animals ? What is true of the stomach in the lower orders of animals ? What peculiarity is there in the Hydra in regard to its stomach ?

C H A P T E R V I I I .

105. What are the different parts of the apparatus of the circulation ? Describe the agency of each in circulating the blood.

106. What relation does the heart bear to the rest of the circulating apparatus ? What is the difference between the arteries and the veins in their structure ? What two reasons are there for this difference ? What is the pulse ? How do the arteries and veins differ in the mode of their division ?

107. How does the venous system differ from the arterial in capacity ? How in regard to rapidity of flow of the blood ? Describe the valves in the veins.

108. Why are these valves needed ? Why is it more dangerous to wound an artery than a vein ? Give some examples, showing how on this account the arteries are seated more deeply than the veins. Where are the arteries superficially situated ?

109. What is the proper way to stop bleeding from an artery ?

110. What is an aneurism ? When a ligature is tied around the artery above the aneurism in a limb, how is the limb to be supplied with blood ? What is the chief agent in the circulation of the blood ? How can you illustrate the contraction and the dilatation of the heart ?

111. What phenomena show that the blood-vessels exert an active agency in circulating the blood ? How does the circulation through the liver show that the capillaries are active agents in circulating the blood ?

113. Why are the veins generally full of blood after death, while the arteries are nearly empty? What is the origin of the term artery? Why do we not in common language speak of the blood as running in the arteries as well as in the veins?

114. What is the color of the blood in the arteries? What color has it in the veins? Where is it changed from red to purple? What other changes besides that of color take place? What would be the consequence if the dark venous blood should be sent to the brain? Where is the change in the blood from purple to red effected? How is the apparatus arranged so as to send the purple blood to the lungs to be changed? Explain the diagram showing the plan of the two circulations?

115. What is the difference in the two circulations as to the color of the blood in the veins and the arteries? What is the difference between the change of the blood in the capillaries of the lungs and that which takes place in the capillaries of the general system?

116. Describe the parts of the right half of the heart as represented in Fig. 70. Describe the manner in which the auricle and ventricle, with the valves, act. Give the illustration as represented in Fig. 71. What is the difference in size and strength, between the auricle and ventricle? What is the size of the heart?

118. Describe the arrangement of the valves of the aorta. Describe the special provision to prevent leaking in these valves. How are the walls of the heart supplied with blood?

120. Describe the valves between the auricles and the ventricles. Why are they regulated by *muscles*? Why are there no valves where the blood pours into the auricle from the vena cavae? Describe the parts of the heart as represented in Fig. 74.

122. Describe the circulation as given in the map of the heart in Fig. 75.

123. Describe the situation of the heart and its blood-vessels, as represented in Fig. 76.

124. What is the difference between the two sounds of the heart? What is the cause of the first sound? What of the second? How is the pulse produced? Explain the impulse of the heart against the chest.

125. Explain the plan of the pericardium.

126. Has the heart any repose? Give some calculations as to the amount of work it does in a lifetime.

C H A P T E R I X.

127. What two objects are effected by the respiration? Of what are the lungs composed? To what is their spongy lightness owing?

How minute are the air-cells or vesicles? In what way is the change produced by the air in them upon the blood?

128. Describe the arrangement of the larynx, the trachea, the bronchi, and the lungs, as exhibited in Fig. 79. How are the heart and the lungs arranged in the chest?

129. What is the pleura? Why are the lungs not fastened to the walls of the chest?

130. Describe the manner in which the air is made to enter the chest in breathing. Describe the framework of the chest, as represented in Fig. 80. How are both lightness and strength secured in this structure? Why are the ribs joined to the breastbone by means of cartilages?

131. What is the chief connecting material of this framework? What is the diaphragm, and how is it arranged?

132. How does the diaphragm act? Describe inspiration and expiration as illustrated by Figs. 81 and 82.

134. In what way do other muscles, besides the diaphragm, act in respiration? Describe their arrangement and action, as represented in Fig. 83.

135. What is the arrangement of the muscular fibres between the ribs, and their mode of action? In what directions are the ribs moved by the muscles in the neck and between the ribs? Do these muscles act much, if at all, in ordinary easy respiration? Under what circumstances do they act strongly? If air were admitted to the outside of the lungs by openings in the walls of the chest, what would be the result?

136. How are the blood and the air kept from mingling in the lungs, while they are brought so near together that the air changes the blood? What experiment shows that blood can be acted upon by air through pores? How important is the office of the air-cells? What provisions are made for securing to them sufficient room under all circumstances? Illustrate by reference to the state of things in violent exercise.

137. If the expansion of the chest be restrained in any way, what influence is exerted upon the air-cells? In what two ways does violent exercise injure the lungs when the chest can not be well expanded?

138. What is said of the influence of compression of the chest in the production of disease in the female sex? What is said of the extent to which compression of the chest is often carried? What is said of the gradual moulding of the chest by continued compression during its growth?

140. How is death produced in drowning? How is water prevented from getting into the lungs in any quantity? If arterial blood could be supplied to all the organs while the breathing is stopped, what would be the result? What contrivance has the whale for this purpose?

141. What is the arrangement of the gills of a fish? By what experiment can you prove that it is the air in the water that acts on the blood in the gills, and thus keeps the fish alive? Why can not the fish use air that is not mingled with water? What provision in the land-crab enables him to live in air as well as in water? Describe the arrangement of the gills in the lob-worm, and the larva of the May-fly.

142. How are the respiratory organs arranged in insects? What is the effect of covering their stigmata with varnish? For what two purposes is the apparatus of respiration largely developed in birds? What special arrangement is there for securing lightness?

144. By what experiment can you show that carbonic acid is thrown off from the lungs? What are the components of the air, and what is their proportion? Which of these is essential to life? Why would it not be well to breathe pure oxygen alone? Where has it been supposed till recently that the oxygen of the air unites with carbon to make carbonic acid? Where does this union take place? What facts settle the last question?

146. Does the change effected by the air upon the blood in the lungs take place to some extent, when blood drawn from a vein is exposed to air? What experiment illustrates the manner in which the air acts on the blood in the lungs?

147. How much carbon is contained in the carbonic acid thrown off from the lungs in twenty-four hours? What effect does this gas produce upon the health if ventilation be imperfect?

148. What becomes of the carbonic acid thrown off from the lungs of animals? How is the air replenished with oxygen? How is the equilibrium preserved in different climates? What effect has light upon the discharge of oxygen from the leaves of plants?

149. By what process is the heat of the body maintained? Trace its analogy to ordinary combustion. What was formerly supposed in regard to the place of the production of animal heat? What objection was made to this supposition? Where was it at length discovered that the heat is made?

150. What are the three sources of *fuel* for keeping up the animal heat? Why is so large a quantity of oily food eaten in cold climates? How do cold and tropical climates differ in the provisions of nature in this respect? How is the use of fat in maintaining heat exemplified in hibernating animals? Whence comes the heat produced by exercise? Why is heat in different animals proportioned to their degree of activity?

151. Contrast the warm and cold-blooded animals in this respect?

152. What is the ordinary temperature of the human body? What is essential to comfort as to temperature in man? Detail experiments which show how high a degree of temperature can be borne.

How are the evil effects of excessive heat in such cases chiefly prevented?

153. How much does the state of torpidity vary in different animals? On what does the degree to which a deprivation of air can be borne depend?

154. How far are the chemical changes described in this chapter dependent on nervous action?

CHAPTER X.

155. By what is the building and repairing of the body done? Have the vessels by which this is done, the power of selecting their material from the blood? Give examples of the co-operation of the formative vessels in their work. How is the concert of action in these vessels illustrated in the definite but various shapes of the structures which they make?

156. Illustrate the agreement necessary between different neighboring sets of formative vessels in the process of growth. Illustrate the wonderfulness of the concert of action in the formative vessels, when there is a change of action. How is this exemplified in certain animals, as the frog?

158. Describe the agreement of action seen in the successive changes that take place in the formation, discharge, and healing of an abscess.

159. How many kinds of waste particles are there? By what absorbents are those particles taken up that can be used again?

160. What organs probably fit them to be used again as a part of the building material? Where is the *lymph*, which they compose, mingled with the blood? By what are the particles that are wholly useless absorbed? By what organs are they excreted or thrown off from the body? Do these various organs excrete different parts of this waste?

161. Give some examples in which other functions besides excretion are performed by the same organ. What are the various functions of the skin? Describe its structure to show how well it is fitted for these functions.

162. How extensive is the tubing of the sweat-glands?

163. What is the difference between insensible and sensible perspiration? What are the sebaceous glands? What purpose do they serve? Where are they most abundant? Upon what does the rapidity of the change constantly going on in the body chiefly depend? Which has the most influence on this change, mental or bodily labor?

164. Illustrate the influence of activity on this change by a com-

parison between the frog and the canary bird. Illustrate the same influence by a comparison between different parts of the body.

165. What is said of the mingling of life and death in the changes of the particles?

CHAPTER XI.

165. By what are all the minute operations of the system performed? How do the cells differ from the cells in the cellular tissue? What do these cells contain? What is to be said of their form?

166. Describe them as seen in the blood. Of what are the solid parts of the body composed?

167. How do the cells appear as seen in the Hydra? Upon what does the character of many of the textures of the body depend? What is the chief difference between the various glands of the body? Upon what do the colors of various parts depend? Illustrate the selecting power of the cells.

168. What is said of the changes that take place in the contents of the cells? How many kinds of cells are there in the blood? What gives the red color to the blood? What are two of the offices of the colored cells?

169. How does their amount vary in different animals, and in different individuals of the human race? Describe by the figure the manner in which absorption is performed on the surface of the mucous membrane in the bowels.

170. Describe in like manner secretion by Fig. 102.

171. How many fibrillæ are there in a muscular fibre? What is each one of these fibrillæ? What takes place in them when the muscle contracts? What is the cause then of the swelling out of a muscle when it acts? How minute are the cells in muscles?

172. What solid animal deposits are made by cells? Describe the arrangement in the enamel of the teeth.

173. Of what are the nerves composed? What has been found in regard to combinations between the tubuli of the nerves? How are these tubuli made from cells? What is the extent of the agency of the cells? In the formation of every animal what precedes the appearance of any diversity of parts?

174. Describe the arrangement of the contents of an egg.

175. Describe the succession of processes that take place in the yolk preparatory to the formation of the bird.

176. From what material are all the parts of the bird made? What is the grand distinction between organized and unorganized substances? What comparison is made between gravitation and cell-life? Compare the exhibition of the Creator's power in the minute

and in the large operations of nature. What comparison can you make between the beauty of nature as seen by the naked eye, and its inner beauty revealed by the microscope?

CHAPTER XII.

178. How far are the functions of nutrition alike in animals and plants?

179. Through what system are the uses for which the body is constructed secured? Why are the functions that are performed through the nervous system, called functions of *animal* life? Why are they also called functions of *relation*? Through what intermediate instrument does this system perform its functions?

180. How does this system vary in complication in different animals? How much is learned through the nerves and their subordinate organs, the organs of the senses? What are the three parts into which the nervous system may be divided?

181. What three things are necessary to sensation? Illustrate the necessity of each. What three things are necessary to voluntary motion? Describe the arrangement of the parts of the nervous system as represented in Fig. 110.

183. Describe the arrangement and structure of the brain as represented in Fig. 111.

184. What part of the nervous system is most immediately essential to the continuance of life? And why? Illustrate by facts. What are the convolutions of the brain?

185. Describe the membranes of the brain—the *pia mater*—the *dura mater*—the *arachnoid*. What is the arrangement of the gray and the white substance? Does the arrangement of the convolutions favor the idea of the phrenologist? Of what is the white substance of the brain composed? What function is performed by it?

187. What tubuli transmit impressions *from* the brain? What transmit *to* it? What is said of the size of the tubuli? What is the function of the gray substance? In proportion to what does its amount vary in different animals? Is there gray matter at the extremities of the nerves? With what are the cells in the gray substance mingled? What is said of the necessity of a supply of arterial blood to this substance?

188. How does the arrangement of the gray and the white substance differ in the brain, in the spinal marrow, and in the ganglions? What are ganglions? What are plexuses? Why is the gray matter so largely supplied with blood?

189. What is said of the manner in which the nerves terminate in

the organs of the body? Where are the Pacinian corpuscles mostly found? Describe their structure. What do we know of their use?

190. What is there that is wonderful in the healing of a divided nerve? What do the observations of M. Séguard show? What fact was proved by the experiments of Dr. Haighton? What nervous changes occur when a union takes place between parts that do not belong together?

192. Do the same nerves answer for sensation and for motion? In what part of the body are nerves of different kinds kept separate? How is it in all other parts? What is the arrangement of the nerves that branch out from the spinal marrow? What two purposes do the two roots of each nerve serve? How is this ascertained?

193. Are there different nerves for different kinds of sensation? How is it in the eye? How in the nose? What is a nerve of *common* sensation? What is a nerve of *special* sensation? Is each nerve fitted for its own peculiar office? Illustrate by reference to the nerves of the eye. Notice particularly the effects produced, if the nerve of common sensation in the eye be paralyzed.

194. Why are different parts of the body endowed with different degrees of sensibility? What organ is more sensitive than any other? How much sensibility have the muscles? How much have the bones? What fact is related to show the use of the sensibility of the skin in preventing injury? What change takes place in the sensibility of internal parts when they become inflamed? What benevolent purpose is there in this?

195. Does a nerve, as a matter of course, have sensibility? What is true of the brain in relation to sensibility? What of the heart? Is the heart well endowed with nerves? With what nerves is it endowed? What is said of the nerves of motion in the face? What are the appearances when the nerve of expression in the face is paralyzed? Why is this nerve called the *respiratory* nerve of the face? How are the motions of expression in the face connected with the motions of respiration? Describe the results when this connection is broken by a paralysis of the respiratory nerve of the face.

197. How many different nerves are devoted to the eye? What are their different offices? Of nerves going to the same part may one be palsied while another is not? Give some illustrations. Give the case related by Sir C. Bell.

198. Are the nerves of different kinds all alike in their structure and composition? Why can not the impression producing sensation be transmitted by the same nerve with the impression producing motion? In what direction is nervous action in sensation? In what direction is voluntary motion?

199. Does voluntary motion occur sometimes in consequence of sensation, and sometimes not? Illustrate this. Give the resemblance

of the nervous system to a telegraphic apparatus. What is true of motion caused by mental emotions? Give some examples of muscles that are wholly involuntary, and of muscles that are partially so.

200. What is the difference between an *excitor* and a *motor* nerve? Illustrate by reference to the respiration—and the action of the muscular coat of the stomach. Why is the action of these two classes of nerves called a *reflex* action? Do we know what is transmitted through the trunk of a nerve? Does reflex action ordinarily occur without positive sensation? Under what circumstances is sensation connected with it? Illustrate by reference to the action of the respiratory muscles.

201. State the two separate functions of the spinal marrow. By what arrangement are they performed? Illustrate the modes of effecting sensation—motion—and reflex action.

202. How does the brain differ from the spinal marrow as to intervals of rest? Illustrate the continuous action of the spinal marrow, as seen in the operations that go on in the system when the brain is asleep, or is torpid with disease. Besides these operations, mention some of the motions that can be excited through the agency of the spinal marrow independent of the brain. Cite some of the facts to show that voluntary muscles act involuntarily more often than is commonly supposed.

203. Explain the involuntary action of muscles in walking and other like acts. What was formerly supposed in relation to the importance of the brain as a central organ of the nervous system? How do we know that the brain is not directly essential to the maintenance of life?

204. What are the functions most essential to life? Upon what part of the spinal marrow do these depend? Illustrate the extent to which the different parts of the spinal marrow are independent of each other. Is there any sensation independent of the brain?

205. Why is the system of nerves, of which I have treated in this chapter, called the *cerebro-spinal* system? What other system is there? What are its purposes?

CHAPTER XIII.

205. What principles apply to the construction of the apparatus of the voice?

206. Into what two kinds are wind-instruments divided? Explain the manner in which the variation of note is produced in those of the first kind, by reference to the flute and the trombone.

207. Illustrate the same point in the operation of the flute-stop of the organ. What influence does the width of the vibrating column of

air have upon the note? How is the note varied in those wind-instruments in which the length of the column of air can not be altered? What are some of the wind-instruments of the second class? How is the sound produced in these? How is the note varied? Illustrate by reference to the reed-stops of the organ. How are the various notes produced in the clarionet?

208. Trace the analogy, in the application of the principles of musical sounds, between the vibrating column of air, the reed, and the strings in such instruments as the piano and violin. Explain the relation of the *tube* of the reed-instrument to the reed.

209. What is the trachea, and of what is it composed? What is the larynx?

210. Describe the parts of the larynx as represented in Fig. 122. Describe particularly the arrangement of the arytenoid cartilages and the vocal ligaments, as represented in Figs. 123 and 124.

211. Describe, by means of Fig. 123, the manner in which the different notes of the voice are produced.

212. How do we know that the lower ligaments are the true vocal chords? Apply now the principles regulating the variation of note in common musical instruments to the vocal apparatus. Give Magendie's experiment.

213. What is the tube of the vocal apparatus, which answers to the tube of a reed-instrument? How many outlets has it? From which does the voice generally issue? How is it in humming? What influence do the cavities of the nose have on the voice?

214. In what two ways is the size of the vibrating column of air in the tube of the vocal instrument varied? What influence does this tube have on the character of the voice? How would the voice sound if it should come directly from the larynx, instead of passing through the tube attached to it?

215. What is said of the variety and precision of the action of the muscles in the modulation and articulation of the voice? How much do the ligaments vary in length in producing all the variety of notes of which the voice is capable? Give the calculation in regard to the minuteness of the muscular action in passing from one note to another. What is said of skill in managing the muscles of the chest in speaking and singing? Give the illustration of the bag-pipe.

216. What is one of the chief causes of "throat disease" in public speakers? What circumstances tend to produce this disease? In the articulation of how many letters is the tongue the chief agent? State some facts to show that the tongue is not so essential to the power of speech as is commonly supposed.

217. What letters are chiefly formed by the teeth? What is lisping? What letters are chiefly formed by the lips? Why do children use labials so early and so freely? Of what are there terms of endear-

ment composed in most languages? Illustrate the agency of the nasal cavities in articulation.

218. Explain the difficulty called speaking through the nose. What is said of articulation in whispering? How is the variation of note in whispering caused? Mention some of the attempts that have been made to imitate the articulation of the voice by mechanism.

CHAPTER XIV.

219. How is sound produced? When is sound musical, and when discordant? What is said of the transmission of sound? What of its reflection?

220. Illustrate the influence of the reflection of sound in accumulating it.

221. What is true of the facility of the transmission of sound through solids and fluids as compared with air? Illustrate it by facts. How is the fact that sonorous vibration does not readily pass from one medium to another, illustrated? Upon what does the degree to which the vibration is lessened in passing from one substance to another, depend?

222. In what cases is the intervention of a membrane of essential service, and why? Give a general description of the process of hearing. Describe the apparatus of hearing, as represented in Fig. 132.

223. What is the object of the external ear? What is the use of its ridges and prominences? What is said of the external ear of animals in comparison with man?

224. Describe the tube of the ear. By what two means is it guarded against intruders? Describe the drum of the ear and the little bones. What is the arrangement of these bones? What are their connections, and how do their muscles act upon them?

225. How does the cavity of the tympanum communicate with the mouth, and why? What part of the ear is the essential part of the apparatus? How much of the apparatus may be destroyed without entire loss of hearing?

226. Describe the parts of the labyrinth. Why is it better that the vibrating substance in the labyrinth be a fluid than a solid or a gaseous substance.

227. Describe now, step by step, the process of hearing. Is all our hearing done in this way?

228. What is said of the two ends of the apparatus of hearing?

C H A P T E R X V.

228. Into what two parts may the process of seeing be divided? What principles govern the construction of the mechanical part of the apparatus? What is the object of its arrangements? How is the second part of the process executed? How does the transmission of light resemble that of sound?

229. What is the *refraction* of light? Illustrate by Fig. 136. How are the rays bent in relation to a perpendicular when they pass from a denser into a rarer medium? How, when they pass from a rarer into a denser?

230. How are the rays refracted when they pass through a medium which has a *concave* surface?

231. How many coats has the eye? Describe the arrangement of the parts of the eye, as represented in Fig. 139. What is the use of the sclerotic coat? How is the cornea fitted into it?

232. What is the color of the choroid coat, and to what is it owing? Of what is the retina chiefly composed? What are the three humors of the eye? Describe the chamber in which the aqueous humor is. What is the consistence of the crystalline humor or lens? Describe the vitreous humor. Why is it called vitreous? Describe the various parts as they are more minutely delineated in Fig. 140. How is the aqueous humor formed? How is it continually changed?

233. Describe the membrane called the conjunctiva. What are the ciliary processes? Describe their arrangement. What is their use?

234. How are images of objects formed upon the retina? How can the fact that such images are formed, be proved?

235. Why are these images inverted? On what does the color of the iris depend? What is the principal office of the iris? By what arrangement of its muscular fibres are its motions effected? What is the office of the crystalline lens? What is its shape? Its structure?

236. What two purposes does the choroid coat serve? What is the state of the choroid coat in the albino? What gives the bright red or pinky hue to the iris in his case? How does the color of the choroid coat vary in different animals? What is the character of the retina, and its office? Trace the analogy between the optic nerve and the other nerves of sense? What resemblance is there to the nerve of touch in its termination?

237. What is the defect in the operation of optical instruments, called spherical aberration, and how is it obviated in the eye?

238. What is the difficulty in the operation of a common lens, called chromatic aberration? How in the eye? Contrast the eye with the telescope in regard to the facility with which the eye accommo-

dates itself to objects at different distances. In what two ways is this accommodation effected?

239. By what defects in the structure of the eye in the near-sighted is this power of adjustment counteracted? How is this difficulty obviated? What is the difficulty in the far-sighted? How is it obviated?

240. What is necessary to single vision in regard to the two images formed in the two eyes? When are the two images in the eyes alike?

241. In what cases are they unlike? Relate the experiment given in explanation. How is it that in such a case, while there are two images, and therefore two impressions sent along the two optic nerves, yet the impression on the mind is single? Explain Professor Wheatstone's stereoscope.

242. What is the *visual angle*? Can we get a correct idea of magnitude by the visual angle alone? Illustrate by the Figure.

243. What circumstance must be known in regard to an object, in order to have our estimate by the visual angle correct?

244. Illustrate the manner in which we get ideas of the magnitude of objects by comparison. Show how we sometimes are made aware of our dependence on this sort of evidence. Explain the use of the muscular sense in acquiring an idea of the size and distance of objects. Do all the images formed on the retina transmit impressions to the mind? Illustrate in reference to ordinary vision by an experiment.

245. What is the "Blind Spot"?

246. How is the eye *situated* so as to protect against injury? How does the cushion of fat on which it rests serve to protect it? In what two ways does the muscle that closes the eyelids serve as a protection to the eye. How is it protected by the eyelashes? How by the eyebrows? How are the eyelids constructed in reference to the protection of the eye?

247. How do the tears serve as a protection? Why do fishes have no tear-apparatus? Describe the arrangement of the tear-apparatus.

248. Why do the tears overflow the edges of the eyelids when they are abundant? What arrangement of glands is there on the eyelids? What two purposes does the oily substance formed by them serve? How are the tears conducted into the mouth of the ducts when the eyelids are closed? Describe the nictitating membrane in the eyes of birds.

CHAPTER XVI.

249. From what two sources are the rules of hygiene to be learned? How far is a knowledge of physiology necessary to a proper understanding of these rules?

250. What division of topics should be made in the subject of hygiene?

251. What points in the hygiene of digestion have been before noticed? What is said in regard to the amount of food needed by the body? How can we know what this amount is? What errors are committed in regard to quantity of food?

252. From what causes is too little food sometimes taken? What is said of the intervals between our meals? What is said of eating regularly?

253. What of the different kinds of food? What of fruits? What influence has the mind on digestion?

254. What is the general statement in regard to the hygiene of respiration? In what two ways is the free access of the air to the lungs interfered with? What general rule is given as to dress in regard to the chest? In what ways does compression of the chest occasion disease?

255. Why ordinarily is the influence of defective aeration (or airing) of the blood not appreciated? What is the office of the organs of the circulation? Is the action of these organs ever violent and tumultuous?

256. What influence has muscular exercise on the development of the organs of the body? How is it a preservative against disease? What is said of violent exercise?

257. What is the change going on continually in all parts of the body? What two conditions are necessary to the proper performance of this change? What is said of the discharge of waste matter from the system? What organs effect this discharge?

258. How much matter is discharged from the skin? How is the animal heat produced? How does exercise increase it? What influence has the quality of the blood upon it?

259. What is essential to a comfortable temperature of the body? When one is too much heated how is the extra heat disposed of? What is the object in covering the body with clothing and in surrounding it with heated air? What is said of cold as a cause of disease? What are our means of guarding against cold?

260. How should we regulate the amount of clothing? What is said of guarding against cold when the body is in a state of rest? What is said of the weak suffering from exposure to cold? How should the shoes of delicate females be made?

261. Under what circumstances does cold act as a stimulant? What circumstances are necessary to this result? What are the conditions on which reaction depends?

262. What rules should be observed in the use of cold bathing? What are the best times for using it? What occasions the wear and tear of the system? When is most of the repairing in the system done?

263. What is said of the relation of exercise to health? What effect has it on the muscles themselves? What on the other textures? How does it prevent deformity?

264. What are the two causes of the common deformity of the spine? Explain their action. Why is this deformity found so much more often in females than in males?

265. How much influence has posture in producing it? What especially debilitates the muscles of the back in the female? Illustrate the necessity of having exercise varied—also of having it general.

266. What is said of gymnastics and calisthenics? What is said of having the exercise habitual? How does too much exercise do harm? What is said of having the exercise agreeable?

267. What is said of the hygiene of the senses? What is said of the necessity of seasons of rest for the brain? What significant fact in regard to insanity shows this? What is said of the conditions under which the mind can perform much labor without harm?

268. What is said of overworking the brain during its growth? What of the manner in which the child's mind is ordinarily exercised? What two mental causes acting together injure the health and sometimes produce insanity?

269. What influence has the regulation of the passions on the health? On what portions of the system do alcohol and tobacco chiefly act? What is said of alcoholic stimulants?

270. Show how tobacco may act indirectly as a stimulant. What are its effects on the system? To what class of persons is it especially injurious? What is the evidence in regard to the influence of tea and coffee?

271. What is said of emanations from filth as producing disease? Give a summary of the chief causes of disease. Is disease commonly produced by any one of these causes alone?

272. What is said of our control over these causes? What other causes of disease are there? To what extent do they act compared with those mentioned? How may we often escape their influence? What is said of the comparative value of preventive and curative measures? Illustrate the prevalent error on this point by reference to consumption. From what does the common neglect of preventive measures arise, and how can this be obviated?

CHAPTER XVII.

273. What is said of the brain as the organ of the mind? What facts show that motion and sensation are dependent on the brain? How does it appear that the mind thinks only by means of the brain? How is life continued when sensation, motion, and thought are stopped

by compression of the brain? How does the variation of the degree of compression vary the effect on the mental functions?

275. Of what is insanity always the result? How do moral causes produce it? If the mind were separate from the body, could insanity be produced in it? Can the disease in the organization in insanity, be always discovered in an examination after death? Describe the situation of the brain and its immediate connections. What is said of the face?

276. Illustrate the rapidity of the communication between the mind and the different parts of the body. How does a child learn to use its muscles?

277. What is said of the amount of knowledge acquired by the child in the first year of his life? What is said of skill in the use of the muscles? What is said of the training of the senses?

278. Illustrate the fact that the senses and muscles are mutual teachers in their training. How does the dependence of the muscles on the senses differ from that of the senses on the muscles? What fact illustrates the absolute dependence of the muscles on the senses? In the education of the muscles and the senses, what is, strictly speaking, educated or trained? Illustrate by reference to the idiot and the deaf-mute. Why does not the education of the muscles extend to those that are involuntary?

279. What difference is there in the different stages of the training of the muscles in the degree of cognizance which the mind takes of their action? Illustrate by reference to learning to walk, to read and to sing. What part of the brain has an especial connection with the mind? What is the chief office of the cerebellum? Give the evidence from comparative anatomy on which this point is settled?

281. What experiments lead to the same conclusion? What is said of the comparative amounts of the white and the gray substance in the brain?

282. In what portion of the brain is the process of thinking carried on? What is the *facial angle*? What is the difference in regard to this between the skull of the European and that of the African? What between the skull of animals and that of man? What is the common measure of this angle in ancient statues of deities and heroes?

283. What is said of the rule that the amount of intelligence, both in man and in animals, is proportioned to the amount of the cerebrum?

284. What facts show that size is far from being the only measure of power in case of the brain? In studying the comparative physiology of the brain, what significant fact do we find when we come to pass from the higher animals to man? Of what character is the mental difference between them and man? What is said of the definiteness of the distinction between man and animals? What note ought to be made of this distinction by the comparative physiologist? What are

the three sources of our knowledge in relation to the connection of the mind and the body? What is the consequence if we rely upon any one of these alone?

285. What is the alternative to which one is driven, if he confine himself to the evidence which physiology furnishes? What course is commonly pursued by those who take this narrow view of the subject? What is said of the distinction between organized and unorganized matter? What are the common suppositions in regard to the endowment of organized or living matter? What is said of those endowments of living matter that are connected with the nervous system?

286. What question now arises in relation to intelligence in its connection with matter? What does physiology show us in regard to this connection? Point out the deficiencies of its teaching in relation to the *nature* of this connection. What is the tendency of its presumptive evidence?

287. Looking at the subject solely in the light of physiology, what would be the conclusion in regard to the dependence of mind on organization, when we observe the origin and growth of a thinking animal? What bearing on this point has the fact, that the intellect grows with the brain and appears at last to perish with it? What fact in comparative physiology is strongly adverse to materialism? In which direction, however, on the whole, does the evidence from physiology, taken alone, preponderate?

288. State the ground of the great need which the physiologist has of the evidence from other sources besides his physiology.

289. What is the testimony of consciousness in relation to the independence of the soul in its action? What in regard to its responsibility for its acts? How far is this testimony acted upon by all, when physiological speculations are left out of view? What does the evidence from consciousness show us in relation to the connection of the mind with the material organization? To what alternative does it drive us?

290. How is this testimony of consciousness treated by the Bible?

291. Illustrate our dependence on the Bible for the proof of the soul's immortality? How may the discrepancies in the evidence from physiology in regard to the connection of the mind and the body be cleared up?

292. What is said of the character of the evidence drawn from consciousness and Revelation? What is said of the presumptive evidence from physiology in comparison with it? What is said of the present moral tendencies of physiological investigations?

CHAPTER XVIII.

293. What was Lord Monboddo's idea of the development of man? What recent theory has an analogy to this? What is true of man and animals in relation to instinct and reason?

294. Do we know what the nature of instinct is? Which can be understood best, the actions of instinct or those of reason? Illustrate this point. What seems to produce the actions of instinct? What influence does the intelligence of the animal exert upon them? What is said of the invariableness of the actions of instinct.

295. Describe the nests of the Baya and the Tailor Bird. What is said of the perfection of the actions of instinct? Why are the cells of the honeycomb made hexagonal? Describe the arrangement of the ends of these cells.

297. Give the fact stated in regard to the angle made by the surfaces at their ends. How is the perfection of the actions of instinct seen in animals that live in communities? Describe the structure of a wasp's nest.

298. Give the description of the habits of the beaver.

300. In what respect may instinct be said to be blind? Illustrate by reference to animals that provide for a progeny which they are never to see.

301. Why is it often difficult to distinguish between the results of reason and those of instinct? What would be true of instinct if it were at all rational? Under what circumstances is there perfection in the actions of instinct? Under what circumstances does it fail? Contrast instinct and reason in this respect. Give some illustrations of the characteristics of instinct alluded to. Give Mr. Broderip's account of the beaver. If the beaver in this case had been guided by reason, what would he have done?

302. How far is the care that animals take of their progeny governed by a blind instinct? What is said of the temporary character of parental affection in their case? In what case is there no affection at all?

303. What degree of intelligence is shown in the power of imitation in animals? How do animals show that they reason? How far did the beaver, whose story is given in § 409, reason? How does the character of the inferences made by animals differ from that of those made by man? Illustrate by reference to Newton and his dog.

304. Of what are the inferences made by animals the results? When the processes of thought in animals are extended and complicated, what is true of them? Illustrate by examples the extent to which mental association may be carried in the animal.

306. How do animals learn the relation of cause and effect? Illus-

trate by examples. How does this knowledge of cause and effect differ in man and in animals? Is the mental difference between man and animals one of degree only?

307. What attribute constitutes the great superiority of the human mind? Show how this attribute is the origin of language in man. What is the character of the language of animals? Why can not they have a language of arbitrary signs? What is the source of man's belief in a Creator? Illustrate this point. Is this belief *implanted* in the mind?

308. What two suppositions have been offered in relation to conscience? What is said of the doubts which some entertain as to the existence of conscience? What is true of those cases in which animals seem to some to have a moral sense? Illustrate the fact that in common language we recognize the difference between man and animals as to the possession of a conscience.

309. Give a summary of the mental differences between man and animals. Give the gradations which we find in the nervous system as we trace the animal kingdom upward.

CHAPTER XIX.

310. Mention some of the contrasts which we find on looking over the human race. How many varieties of the race are commonly reckoned?

311. What are the characteristics of the Caucasian variety? What are the characteristics of the Ethiopian varieties—the Mongolian—the American?

312. What are the characteristics of the Malay variety? What is said of the extent to which the race may be divided into varieties? What is said of the way in which national differences are produced? What is the opinion of most naturalists in regard to the production of the races? What is the doctrine of Professor Agassiz and others? State the grounds on which he bases his doctrine. What is his opinion in regard to climatic and other influences? What is his opinion of the history given in Genesis? Are the different branches of the race in his view different species, or mere varieties? What is the distinction between a species and a variety?

315. Mention the influences included in the expression, *climatic and other influences*. What is said of the influence of climate? What is the circumstance which has most influence in producing varieties in man and in animals? What is included in the term *domestication*? What is the precise question in regard to climatic and other influences?

316. Mention some facts that show that climate has a great influence on the color of the race. What influence do intellectual and moral causes exert upon the shape of the head?

317. What is said of certain changes in form produced by causes the operation of which we do not understand? What are the three different types of form in the head stated by Dr. Pritchard, and by what causes are they produced? State in regard to each:—the *prognathous*—the *pyramidal*—the *oval*.

318. Give some facts showing that these types are convertible into each other. What is said of the insensible gradations by which the varieties of the race pass into each other?

319. What effect has the influence of domestication on both man and animals? What two objections are brought against the alleged competency of climatic and other influences to produce the varieties of the race? What great fact is a sufficient reply to these objections?

320. Apply this fact in explanation of the production of the varieties of the human race. What is said of the analogy thus drawn between man and animals, in comparison with that which Professor Agassiz has tried to establish? What consideration weakens his analogy? If the climatic and other influences appear to any one incompetent to produce the varieties of the race, is he driven necessarily to admit its multiple origin?

321. What is said of the occasional introduction of new causes by the Creator? Upon what do our calculations upon the regularity of nature depend? What is said of the change in the age of man effected at the time of the flood?

322. What is said of the occasional appearance of new diseases? What is said of the convulsions which have evidently taken place in the earth? Does it make any difference to the argument, whether the results came directly from causes, or from a chain of causes?

323. Apply the argument to the production of the varieties of the race. What is said of the objection to the argument, that it is supposing a miraculous interposition?

324. Is the supposition thus made needed? What is said of it in comparison with the supposition of Agassiz? On what principles is the testimony of the Bible as to the origin of the race to be interpreted? What are the main facts which it gives in relation to it? How is the truth of its testimony confirmed? Of what force is analogical and presumptive evidence in opposition to it? Is any fear to be entertained in regard to bringing the Bible to the test of ascertained facts?

C H A P T E R X X .

325. What is said of the diversity in the manifestations of life? How is life always the same in relation to its origin? Remark on the wonderful variety of results worked out by the vital force beginning in a simple cell.

326. How is life always essentially the same in its processes as well as in its origin? Do we know what life is? How does the vital force differ from such forces as light, heat, and electricity, in regard to its power of diffusion? How in regard to self-generation? How in regard to the variety of its effects?

327. Do we know whether life is one thing? What is said of the supposition that the principle of life resides chiefly in the blood? What are the relations that exist in living bodies between the laws of chemistry and mechanics and those of life? Illustrate this point?

328. What is said of the materials of which the human body is composed, and of the degree of heat in which they are kept? Show the difference in the operation of heat on dead and on living matter, as seen in the egg.

329. How is the power of the vital force exhibited in the uniformity of the heat of the body? What is said of the changes going on by the operation of the vital force? Remark on the dormant condition of this force in the case of seeds.

330. Remark on the analogy between the hibernation of animals and the state of most of the vegetable world in winter. What portions of the human system are some of the time dormant, and why? What is the most mysterious circumstance in regard to the vital force? Show how the soul and the vital force are two distinct, and, in some measure, opposing forces. In what different senses are they both present everywhere in the system?

331. What is said of the development of the soul in the body? What of the mystery of this connection? What is said of the limit of the vital force? Has the vital force a natural limit?

332. What is the distinction between *systemic* and *molecular* death? How may death begin in the *circulating* system?

333. Give the three classes of causes by which death may begin in the *respiratory* system. Give examples of death beginning in the nervous system.

334. Illustrate the fact that death is commonly a complex event. What is said of the signs of death? What is said of the clearness of the evidence in all ordinary cases in regard to the fact of death?

335. In the very few cases in which there is any doubt, what course should be pursued? What light can physiology give us in relation to what is beyond this life? What is said of the conjectures on this subject which its investigations may prompt?

G L O S S A R Y.

- Ab-do'men***, (Latin *abdere*, to conceal.) The largest cavity of the body, containing the liver, stomach, intestines, etc.; the belly.
- Ab-duc'tor***, (L. *abducere*, to lead away.) A muscle which moves certain parts, by separating them from the axis of the body.
- Ab-sor'bents***, (L. *ab*, and *sorbere*, to suck up.) The vessels which take part in the process of absorption.
- Ab-sorp'tion***. The process of sucking up fluids by means of an animal membrane.
- A-ce-tab'u-lum***, (L. *acetum*, vinegar.) The socket for the head of the thigh-bone; an ancient vessel for holding vinegar.
- Ac'id, Ac'etic***, (L. *acetum*, vinegar.) Relating to acetic acid. This is always composed of oxygen, hydrogen, and carbon, in the same proportion.
- Ac'id, Lactic***, (L. *lac*, milk.) The acid ingredient of sour milk; the gastric juice also contains it.
- A-chil'les***. A term applied to the tendon of two large muscles of the leg.
- A-cro'mi-on***, (Gr. *akρος*, *akros*, highest, and *ωμος*, *omos*, shoulder.) A process of the scapula that joins to the clavicle.
- Ad-duc'tor***, (L. *adducere*, to lead to.) A muscle which draws one part of the body toward another.
- Al-bu'men*** or Albumin, (L. *albus*, white.) An animal substance resembling white of egg.
- Al-bu'mi-nose***, (from *albumen*.) A soluble animal substance produced in the stomach by the digestion of the albuminoid substances.
- Al-bu'min-oid*** substances. A class of proximate principles resembling albumen; they may be derived from either the animal or vegetable kingdoms.
- Al'i-ment***, (L. *alere*, to nourish.) That which affords nourishment; food.
- Al-i-men'ta-ry Ca-nal***, (from *aliment*.) The tube in which the food is digested, or prepared for reception into the system.
- Al've-o-lar***, (L. *alveolus*, a socket.) Pertaining to the sockets of the teeth.

- An-aes-thet'ics**, (Greek *av*, *an*, without: *aισθησια*, *isthesia*, feeling.) Those medicinal agents which prevent the feeling of pain, such as chloroform, laughing-gas, etc.
- A-nas'to-mose**, (Gr. *ava*, *ana*, through, and *στομα*, *stoma*, mouth.) The communication of arteries and veins with each other.
- A-nat'o-my**, (Gr. *ava*, *ana*, through, and *τομη*, *tomē*, a cutting.) The description of the structure of animals. The word *anatomy* properly signifies dissection.
- An-i-mal'cule**, (L. *animal'culum*, a small animal.) Applied to animals which can only be seen with the aid of the microscope. *Animalculum* (plural, *animalcula*) is used with the same meaning.
- A-or'ta**, (Gr. *ἀόρτη*, from *ἀἴρειν*, *airein*, to lift, to be lifted up.) The largest artery of the body, and main trunk of all the arteries. It arises from the left ventricle of the heart.
- Ap-o-neu-ro'sis**, (Gr. *απο*, *apo*, from, and *νευρον*, *neuron*, a nerve.) The membranous expansions of muscles and tendons. The ancients called every white tendon *neurovo*, a nerve.
- A'que-ous Humor**, (L. *aqua*, water.) The watery colorless fluid occupying the space between the cornea and crystalline lens.
- A-rach'noid Mem'brane**, (Gr. *ἀράχνη*, *arachne*, a cobweb, and *ειδος*, *eidos*, like,) An extremely thin covering of the brain and spinal cord. It lies between the *dura mater* and the *pia mater*.
- Ar'bor Vi'tae**, (L. *the tree of life*.) A name given to the peculiar appearance presented by a section of the cerebellum.
- Ar'ter-y**, (Gr. *ἀίρη*, *aer*, air, and *τίρειν*, *terein*, to contain.) A vessel by which blood is conveyed from the heart. It was supposed by the ancients to contain air; hence the name.
- Ar-tic-u-la'tion**, (L. *articulare*, to form a joint.) The more or less movable union of bones, etc.; a joint.
- A-ryt'e'noid**, (Gr. *αρυταινα*, *arytaina*, a ewer, and *ειδος*, *eidos*, form.) The name of a cartilage of the larynx.
- As-phyx'i-a**, (Gr. *a*, *a*, not, and *σφυξις*, *sphyxis*, pulse.) Originally, want of pulse; now used for suspended respiration, or apparent death.
- As-trag'a-lus**, (Gr.) The name of a bone of the foot. One of the tarsal bones.
- As-sim-i-la'tion**, (L. *ad*, to, and *similis*, like.) The conversion of food into living tissue.
- Au-di'tion**, (L. *audire*, to hear.) The act of hearing sounds.
- Au'di-to-ry Nerve**. The special nerve of hearing.
- Au'ri-cle**, (L. *auris*, the ear.) A cavity of the heart.
- Ax-il'la**, (L.) The arm-pit.
- A-zote'**, (Gr. *a*, *a*, not, and *ζωη*, *zoē*, life.) Nitrogen. One of the constituent elements of the atmosphere. So named because it will not sustain life..

- Bel-la-don'na,** (It. beautiful lady.) A vegetable narcotic poison. It has the property of enlarging the pupil, and thus increasing the brilliancy of the eye.
- Bi-cus'pid,** (L. *bis*, two, and *cuspis*, prominence.) The name of the fourth and fifth teeth on each side of the jaw.
- Bile,** (L. *bilis*.) A yellow viscid fluid secreted by the liver.
- Bronch'i,** (Gr. *βρογχος*, *bronkos*, the windpipe.) The two great divisions or branches of the trachea.
- Bronch'i-al Tubes.** The smaller branches of the trachea within the substance of the lungs, terminating in the air-cells.
- Bronch-i'tis,** (from *bronchia*, and *itis*, an affix.) An inflammation of the larger bronchial tubes.
- Bur'sae Mu-co'sa,** (L. *bursa*, a purse, and *mucosa*, viscous.) Small sacs, containing a viscid fluid, situated about the joints, under tendons.
- Cal-ca-re'ous,** (L. *calx*, lime.) Containing lime.
- Ca-nine',** (L. *canis*, a dog.) Name given to the third tooth on each side of the jaw; in the upper jaw it is also known as the eye-tooth.
- Cap'il-la-ry,** (L. *capill'ius*, a hair, *capilla'ris*, hair-like.) The name of the extremely minute blood-vessels connecting the veins.
- Car-bon'ic Ac-id, or Car'bon Diox-ide,** (CO_2 .) The gas which is expired from the lungs.
- Car'di-ac,** (Gr. *καρδία*, *kardia*, the heart.) The upper orifice of the stomach near the heart; hence its name.
- Cur-niv'o-rous,** (L. *ca'ro*, flesh, and *vora're*, to devour.) Subsisting upon flesh.
- Cu-rot'id,** (Gr. *καρός*, *karos*, lethargy.) The great arteries of the neck that convey blood to the heart. The ancients supposed drowsiness to be seated in these arteries.
- Ca'se-ine,** (L. *caseus*, cheese.) The albuminoid substance of milk; it forms the basis of cheese.
- Car'ti-lage,** (L. *cartilago*.) Gristle. A smooth, elastic substance, softer than bone.
- Ca've,** (L.) Hollow. *Vena cava.* A name given to the two great veins of the body.
- Cer-e-be'lum,** (diminutive of *cer'ebrum*, the brain.) The little brain, situated beneath the cerebrum.
- Cer'e-brum,** (L.) The brain proper, occupying the entire upper portion of the skull.
- Cere-bro-Spi'nal.** Relating to the brain and spine.
- Chor'da-æ,** (L.) A cord. An assemblage of fibers.
- Cho'roid,** (Gr. *χόριον*, *chorion*, a membrane or covering.) The middle tunic or coat of the eyeball.
- Chyle,** (Gr. *χυλός*, *chulos*, juice.) The milk-like fluid formed in the intestines by the digestion of fatty articles of food.

- Chyne,** (Gr. *χυμος*, *chumos*, juice.) A kind of grayish pulp formed from the food in the stomach.
- Cil'i-a,** (pl. of *cil'i-um*, an eyelash.) Minute hair-like processes found upon the cells of the air-passages, and other parts that are habitually moist.
- Cin-e-ri'tious,** (L. *cinis*, ashes.) Having the color of ashes.
- Cir-cu-la'tion,** (L. *circulare*, to move in a circle.) The circuit or course of the blood through the blood-vessels.
- Clav'i-cle,** (L. *clavicula*, from *clavis*, a key.) The collar-bone; so called from its resemblance in shape to an ancient key.
- Co-ag-u-la'tion,** (L. *coagulare*, to curdle.) Applied to the process by which the blood clots or solidifies.
- Coch'le-a,** (Gr. *κοχλω*, *kochlo*, to twist; or L. *cochlea*, a screw.) A cavity of the ear resembling in form a snail shell.
- Co'l-on,** (Gr.) A portion of the large intestine.
- Col-um'na, œ,** (L.) A column or pillar.
- Con'dyle,** (Gr. *κονδύλος*, *kondulos*, a knuckle, a protuberance.) A prominence on the end of a bone.
- Con-junc-ti'vea,** (L. *con*, together, and *jungare*, to join.) The membrane that covers the anterior part of the globe of the eye.
- Con-trac-til'i-ty,** (L. *con*, and *trahere*, to draw together.) The property of a muscle which enables it to contract, or draw its extremities closer together.
- Con-vo-lu'tions,** (L. *con* and *volv̄re*, to roll together.) The tortuous foldings of the external surface of the brain.
- Cor'ne-a,** (L. *cor'nu*, a horn.) The transparent membrane which covers the anterior fifth of the eyeball.
- Cor'pus-cles,** Blood, (L. dim. of *cor'pus*, a body.) The small biconcave disks which give to the blood its red color; the white corpuscles are globular and larger.
- Cost'a,** (L. *costa*, a coast, side, or rib.) A rib.
- Cra'ni-al,** (L. *cra'nium*, the skull.) Pertaining to the skull. As the cranial nerves.
- Cri'coid,** (Gr. *κρικος*, *krikos*, a ring.) A cartilage of the larynx, resembling in shape a seal ring.
- Crys'tal-line Lens,** (L. *crystal'lum*, a crystal.) One of the humors of the eye; a double convex body situated in the front part of the eyeball.
- Cu'ti-cle,** (L. dim. of *cu'tis*, the skin.) The scarf-skin; also called the *epider'mis*.
- Cu'tis,** (Gr. *σκυτος*, *skutos*, the skin or hide.) The true skin, lying beneath the cuticle; also called the *der'ma*.
- De-cus-sa'tion,** (L. *decus'sis*, the Roman numeral ten, X.) A reciprocal crossing of fibres from side to side.
- Di'a-phragm,** (Gr. *διαφραγμα*, *diaphragma*, a partition.) The

- midriff; a muscle separating the cavity of the chest from the abdomen.
- Di-as-to-le,** (Gr. διαστέλλειν, *diastellein*, to put asunder.) The dilation of the heart and arteries when the blood enters them.
- Dor'sal,** (L. *dorsum*, the back.) Pertaining to the back.
- Du-o-de'num,** (L. *duode'ni*, twelve.) The first division of the small intestines.
- Du'ra Ma'ter,** (L. *durus*, hard, and *mater*, mother.) The outermost membrane of the brain.
- E-mul'sion,** (L. *emulgere*, to milk.) Oil in a finely divided state suspended in water.
- En-am'el,** (Fr. *email*.) The smooth hard material which covers the crown or visible part of the tooth.
- Ep-i-glot'tis,** (Gr. επί, *epi*, upon, and γλώττα, *glottia*, the tongue.) One of the cartilages of the glottis.
- Eu-sta'chi-an Tube.** A channel from the fauces to the middle ear, named from Eustachius, who first described it.
- Ex-pi-ra'tion,** (L. *exspirā're*, to breathe out.) The act of forcing air out of the lungs.
- Ex-ten'sion,** (L. *ex*, out, and *tendere*, to stretch.) The act of restoring a limb, etc., to its natural position after it has been flexed, or bent; the opposite of *Flexion*.
- Fas'ci-a,** (L. *fascia*, a band.) A tendinous expansion or aponeurosis.
- Fe-nes'tra,** (L.) Literally, a window; the opening between the middle and internal ear.
- Fi'bri'n.** A peculiar organic substance found in animals and vegetables; it is solid, tough, elastic, and composed of thready fibers.
- Flex'i'on,** (L. *flexere*, to bend.) The act of bending.
- Fib'u-la,** (L. a clasp.) The outer and lesser bone of the leg.
- Fol'li-cle,** (L. *folliculus*, a small bag.) A gland; a little bag in animal bodies.
- Gan'gli-on,** (Gr. γαγγλιον, *ganglion*, a knot.) A knot-like swelling in the course of a nerve; a smaller nerve-center.
- Gas'tric,** (Gr. γαστήρ, *gastēr*, stomach.) Pertaining to the stomach.
- Gland,** (L. *glans*, an acorn.) An organ consisting of follicles and ducts, with numerous blood-vessels interwoven; it separates some particular fluid from the blood.
- Glos'so-phar-yne'al Nerve,** (Gr. γλῶσσα, *glossa*, the tongue, and φάρνξ, *pharinx*, the throat.) The nerve of taste supplying the posterior third of the tongue; it also supplies the throat.
- Glot'tis,** (Gr.) The narrow opening at the upper part of the larynx.
- Gus'ta-to-ry Nerve.** The nerve of taste supplying the front part of the tongue; a branch of the "fifth" pair.
- Hem'or-rhage,** (Gr. ἀἷμα, *hai'ma*, blood, and ρήγνυμι, *rēgnumi*, to burst.) Bleeding, or the loss of blood.

- He-pat'ic***, (Gr. *ἡπαρ, hepar*, the liver.) Pertaining to the liver.
- Hy'gi-ene***, (Gr. *ὑγίεια, hygieia*, health.) The art of preserving health and preventing disease.
- In-cis'or***, (L. *incidere*, to cut.) Applied to the four front teeth of both jaws, which have sharp cutting edges.
- Il'e-um***, (Gr. *εἰλεῖν, eilein*, to wind.) A portion of the small intestines.
- In-sal-i-va'tion***, (L. *in*, and *sali'va*, the fluid of the mouth.) The mingling of the saliva with the food during the act of chewing.
- In-spi-ra'tion***, (L. *in*, and *spird're*, to breathe.) The act of drawing in the breath.
- In-teg'u-ment***, (L. *in*, and *teḡere*, to cover.) The skin, or outer covering of the body.
- Iris***, (L. *iris*, the rainbow.) The thin muscular ring which lies between the cornea and crystalline lens, and which gives the eye its brown, blue, or other color.
- In-ter-cost'al***, (L. *inter*, between, and *costa*, a rib.) Between the ribs.
- Je-ju'num***, (L. empty.) A portion of the small intestine.
- Ju'gu-lar***, (L. *jugulum*, the neck.) Relating to the throat. The great veins of the neck.
- Lab'y-rinth***, (Gr.) The internal ear, so named from its many windings.
- Lach'ry-mal***, (L. *lachryma*, a tear.) Pertaining to tears.
- Lac'te-al***, (L. *lac*, milk.) A small vessel or tube of animal bodies for conveying chyle from the intestine to the thoracic duct.
- Lar'ynx***, (Gr.) The cartilaginous tube situated at the top of the windpipe, or trachea; the organ of the voice.
- Lens***, (L.) Literally, a lentil; any transparent substance so shaped as either to converge or disperse the rays of light.
- Lig'a-ment***, (L. *ligāre*, to bind.) A strong fibrous material binding bones or other solid parts together.
- Lymph***, (L. *lympha*, spring-water.) The colorless, watery fluid conveyed by the lymphatic vessels.
- Mar'row***, (Sax.) The soft, fatty substance contained in the central cavities of the bones. (The spinal marrow, however, is composed of nervous tissue.)
- Mas-ti-ca'tion***, (L. *masticā're*, to chew.) The act of cutting and grinding the food to pieces by means of the teeth.
- Me-dul'la Ob-lon-ga'ta***. The "oblong marrow," or nervous cord, which is continuous with the spinal cord within the skull.
- Mem-bra'na Tym'pan-i***, (L.) Literally, the membrane of the drum; a delicate partition separating the outer from the middle ear.
- Mem'brane***. A thin layer of tissue serving to cover some part of the body.

- Mi'tral,** (L. *mitra*, a mitre.) The name of the valves in the left side of the heart.
- Mo'lar,** (L. *mola*, a mill.) The name of some of the large teeth.
- Mo'tor,** (L. *movēre*, to move.) Causing motion; the name of those nerves which conduct to the muscles the stimulus which causes them to contract.
- Mu'cous Mem'brane.** The thin layer of tissue which covers those internal cavities or passages which communicate with the external air.
- Mu'cus.** A viscid fluid secreted by the mucous membrane, which it serves to moisten and defend.
- Na'sal,** (L. *na'sus*, the nose.) Pertaining to the nose; the *nasal cavities* contain the distribution of the special nerve of smell.
- Nerve,** (Gr. *neūpon*, *neuron*, a cord or string.) A glistening, white cord of cylindrical shape, connecting the brain or spinal cord with some other organ of the body.
- Nu-tri'tion,** (L. *nutrire*, to nourish.) The processes by which the nourishment of the body is accomplished.
- Oc'ci-put,** (L. *ob* and *caput*, the head.) The hinder part of the head.
- OE-soph'a-gus,** (Gr.) Literally, that which carries food. The tube leading from the throat to the stomach.
- Ol-fac'to-ry,** (L. *olfacere*, to smell.) Pertaining to the sense of smell.
- Op'tic,** (Gr. *οπτικός*, from the root *οπτ-*, future *οψομαι*, *opsomai*, to see.) Pertaining to the sense of sight.
- Or'bit,** (L. *or'bis*, the socket.) The bony socket or cavity in which the eyeball is situated.
- Os'mose,** (Gr. *ωσμός*, *osmos*, a thrusting or impulsion.) The process by which liquids are impelled through a moist membrane.
- Os'se-ous,** (L. *os*, a bone.) Consisting of, or resembling bone.
- Pal'ate,** (L. *pala'tum*, the palate.) The roof of the mouth, consisting of the hard and soft palate.
- Pal'mar.** Relating to the palm of the hand.
- Pan'cre-as,** (Gr. *πάσ*, *pas*, all, and *κρέας*, *kreas*, flesh.) A long, flat gland situated near the stomach.
- Pa-pil'la, æ,** (L.) Small conical prominences.
- Pa-ren'chy-ma,** (Gr. *παρεγχειν*, *parengchein*, to pour through.) The substance contained between the blood-vessels of an organ.
- Pa-rot'id,** (Gr. *παρα*, *para*, near, and *ωτος*, *otos*, the ear.) The name of the largest salivary gland.
- Pa-tel'la,** (L. dim. of *pat'ina*, a pan.) The knee-pan; a small bone.
- Pel'ves,** (L.) Literally, a basin; the bony cavity at the lower part of the trunk.

- Pep'sin**, (Gr. πέπτειν, *peptin*, to digest.) The proximate organic element of the gastric juice.
- Per-i-car'di-um**, (Gr. περι, *peri*, around, and καρδία, *kardia*, the heart.) A membrane that incloses the heart.
- Per-i-cra'ni-um**, (Gr. περι, *peri*, and κρανίον, *kranion*, the cranium.) A membrane that invests the skull.
- Per-i-to-ne'u'm**, (Gr. περιτείνειν, *periteinein*, to stretch around.) The investing membrane of the stomach, intestines, and other abdominal organs.
- Per-spi-ra'tion**, (L. *perspirare*, to breathe through.) The sweat, or watery exhalation of the skin; when visible, it is called *sensible* perspiration, when invisible, it is called *insensible* perspiration.
- Phar'ynx**, (Gr. φάρυγξ, *pharunx*, the throat.) The cavity between the back of the mouth and cesophagus.
- Phys-i-o-lo'gy**, (Gr. φύσις, *phusis*, nature, and λόγος, *logos*, a discourse.) The science of the functions of living, organized beings.
- Pi'a Ma'ter**, (L.) Literally, the tender mother; the innermost of the three coverings of the brain.
- Pleu'ra, æ**, (Gr. πλευρά, *pleura*, the side.) A thin membrane that covers the inside of the thorax, and also forms the exterior coat of the lungs.
- Pneu-mo-gas'tric**, (Gr. πνεύμων, *pneumon*, the lungs, and γαστήρ, *gaster*, the stomach.) The name of a nerve distributed to the lungs and stomach; it is the principal nerve of respiration.
- Proc'ess**, (L. *procedere*, to proceed, to go forth.) Any projection from a surface. Also, a method of performance; a procedure.
- Pty'a-lin**, (Gr. πτυίαλον, *ptualon*, saliva.) The peculiar organic ingredient of the saliva.
- Pul'mo-na-ry**, (L. *pul'mo*, *pulmo'nis*, the lungs.) Pertaining to the lungs.
- Py-lo'rūs**, (Gr. πυλωρός, *pulōros*, a gate-keeper.) The lower opening of the stomach, at the beginning of the small intestine.
- Res-pi-ra'tion**, (L. *re*, again, and *spirare*, to breathe.) The act of breathing. Inspiring air into the lungs and expelling it again.
- Ret'i-na**, (L. *re'te*, a net.) The innermost of the tunics or coats of the eyeball, being an expansion of the optic nerve.
- Sa'crum** (L. sacred.) The bone which forms the posterior part of the pelvis, and is a continuation of the spinal column.
- Sa-li'vu**, (L.) The fluid which is secreted by the salivary glands.
- Scler-rot'ic**, (Gr. σκληρός, *skleros*, hard.) The tough, fibrous outer tunic of the eyeball.
- Se-cre'tion**, (L. *secer'no*, *secre'tum*, to separate.) The process of separating from the blood some essential important fluid; which fluid is also called a secretion.

- Se'rum,** (L.) The watery constituent of the blood, which separates from the clot during the process of coagulation.
- Sta'pes,** (L.) Literally, a stirrup ; one of the small bones of the tympanum, or middle ear, resembling somewhat a stirrup in shape.
- Skel'e-ton,** (Gr. σκελλω, *skellos*, to dry.) The aggregate of the hard parts of the body ; the bones.
- Sub-lin'gual,** (L. *sub*, under, and *lingua*, the tongue.) Situated under the tongue.
- Sub-max'il-la-ry,** (L. *sub*, under, and *maxilla*, the jaw-bone.) Located under the jaw.
- Syn-o-vi-a,** (Gr. οὐράνιον, *wón*, *oon*, resembling an egg.) The lubricating fluid of joints, so called because it resembles the white of egg.
- Sys'to-le,** (Gr. συστέλλω, *sustello*, to contract.) The contraction of the heart, by which the blood is expelled from that organ.
- Tac'tile,** (L. *tactus*, touch.) Relating to the sense of touch.
- Ten'don,** (Gr. τείνειν, *teinein*, to stretch.) A hard, insensible cord, or bundle of fibers, by which a muscle is attached to a bone.
- Tho'rax,** (Gr. θώραξ, *thorax*, a breastplate.) The upper cavity of the trunk of the body, containing the lungs, heart, etc. ; the chest.
- Thy'roid,** (Gr. θύρεος, *thureos*, a shield.) The largest of the cartilages of the larynx ; its angular projection in the front of the neck is called "Adam's apple."
- Tra'che-a,** (Gr. τραχὺς, *trachys*, rough.) The windpipe.
- Tym'pa-num,** (Gr. τύμπανον, *tumpánon*, a drum.) The cavity of the middle ear, resembling a drum in being closed by two membranes, and in having communication with the atmosphere.
- U'vu-la,** (L. *uva*, a grape.) The small pendulous body attached to the back part of the palate.
- Vas'cu-lar,** (L. *vas'culum*, a little vessel.) Pertaining to, or containing blood-vessels.
- Ve'no-us,** (L. *ve'na*, a vein.) Pertaining to, or contained within a vein.
- Ver-te-brul Column,** (L. *ver'tebra*, a joint.) The back-bone, consisting of twenty-four separate bones, called vertebræ, firmly jointed together ; also called the spinal column and spine.
- Ves'ti-bule.** A portion of the internal ear, communicating with the semicircular canals and the cochlea ; so called from its fancied resemblance to the vestibule or porch of a house.
- Vil'li,** (L. *vil'lus*, the nap of cloth) Minute thread-like projections found upon the internal surface of the small intestine, giving it a velvety appearance.
- Vit're-ous,** (L. *vi'rum*, glass.) Having the appearance of glass ; applied to the humor occupying the largest part of the cavity of the eyeball.
- Viv-i-sec'tion,** (L. *vi'rus*, alive, and *secare*, to cut.) The practice of operating upon living animals, for the purpose of studying physiological processes.

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